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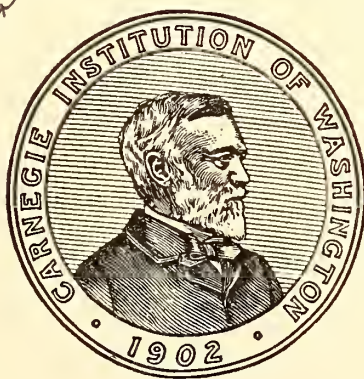
CARNEGIE INSTITUTION OF WASHINGTON

YEAR BOOK No. 32

JULY 1, 1932—JUNE 30, 1933

WITH ADMINISTRATIVE REPORTS THROUGH DECEMBER 15, 1933

Copy for Director's Office



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WASHINGTON, 1933

JUDD & DETWEILER, INC.
WASHINGTON, D. C.

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PRESIDENT

JOHN C. MERRIAM

FORMER PRESIDENTS

*DANIEL COIT GILMAN, 1902-04

*ROBERT SIMPSON WOODWARD, 1904-20

BOARD OF TRUSTEES

ELIHU ROOT, *Chairman*

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FREDERICK H. GILLET	JOHN J. PERSHING	GEORGE W. WICKERSHAM

EXECUTIVE COMMITTEE: HENRY S. PRITCHETT, *Chairman*; FREDERIC A. DELANO,
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STEWART PATON, ELIHU ROOT, FREDERIC C. WALCOTT

FINANCE COMMITTEE: HENRY S. PRITCHETT, *Chairman*; WM. CHURCH OSBORN,
GEORGE W. WICKERSHAM

AUDITING COMMITTEE: FREDERIC A. DELANO, *Chairman*; HOMER L. FERGUSON,
WILLIAM BENSON STOREY

FORMER TRUSTEES

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*ROBERT S. BROOKINGS	1910-29	*WAYNE MACVEAGH	1902-07
*JOHN L. CADWALADER	1903-14	*DARIUS O. MILLS	1902-09
*JOHN J. CARTY	1916-32	*S. WEIR MITCHELL	1902-14
*CLEVELAND H. DODGE	1903-23	*WILLIAM W. MORROW	1902-29
*WILLIAM E. DODGE	1902-03	*JAMES PARMELEE	1917-31
*CHARLES P. FENNER	1914-24	*WM. BARCLAY PARSONS	1907-32
SIMON FLEXNER	1910-14	GEORGE W. PEPPER	1914-19
*WILLIAM N. FREW	1902-15	*JULIUS ROSENWALD	1929-31
*LYMAN J. GAGE	1902-12	*MARTIN A. RYERSON	1908-28
*DANIEL C. GILMAN	1902-08	*JOHN C. SPOONER	1902-07
*JOHN HAY	1902-05	*WILLIAM H. TAFT	1906-15
*MYRON T. HERRICK	1915-29	*WILLIAM S. THAYER	1929-32
*ABRAM S. HEWITT	1902-03	*CHARLES D. WALCOTT	1902-27
*HENRY L. HIGGINSON	1902-19	*HENRY P. WALCOTT	1910-24
*ETHAN A. HITCHCOCK	1902-09	*ANDREW D. WHITE	1902-16
*HENRY HITCHCOCK	1902-02	*EDWARD D. WHITE	1902-03
*WILLIAM WIRT HOWE	1903-09	*HENRY WHITE	1913-27
*CHARLES L. HUTCHINSON	1902-24	*ROBERT S. WOODWARD	1905-24
*SAMUEL P. LANGLEY	1904-06	*CARROLL D. WRIGHT	1902-08

*Deceased

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

STAFF OF INVESTIGATORS

Department of Embryology:

Organized 1914; Franklin P. Mall, Director 1914-1917.

GEORGE L. STREETER, Director

CARL G. HARTMAN

CHIESTER H. HEUSER

MARGARET R. LEWIS

WARREN H. LEWIS

C. W. METZ

Department of Genetics:

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics.

CHARLES B. DAVENPORT, Director

A. F. BLAKESLEE, Assistant Director

H. H. LAUGHLIN, Assistant Director

A. G. AVERY

H. J. BANKER (Retired)

R. W. BATES

A. DOROTHY BERGNER

M. DEMEREC

E. C. MACDOWELL

OSCAR RIDDLE

SOPHIA SATINA

M. STEGGERDA

Geophysical Laboratory:

Organized 1906, opened 1907.

ARTHUR L. DAY, Director

L. H. ADAMS

TOM BARTH

N. L. BOWEN

C. N. FENNER

R. E. GIBSON

R. W. GORANSON

J. W. GREIG

J. H. HIBBEN

F. C. KRACEK

C. J. KSANDA

H. E. MERWIN

G. W. MOREY

CHARLES S. PIGGOT

EUGENE POSNJAK

H. S. ROBERTS

J. F. SCHAIRER

E. S. SHEPHERD

GEORGE TUNELL

H. S. WASHINGTON

WALTER P. WHITE

FRED E. WRIGHT

E. G. ZIES

Division of Historical Research:

Department of Historical Research was organized in 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

A. V. KIDDER, Chairman

Section of Aboriginal American History:

SYLVANUS G. MORLEY

EARL H. MORRIS

H. E. D. POLLOCK

O. G. RICKETSON JR.

H. B. ROBERTS

KARL RUPPERT

A. LEDYARD SMITH

Section of United States History:

EDMUND C. BURNETT (Retired)

CHARLES O. PAULLIN

FRANCE SCHOLES

LEO F. STOCK

Section of the History of Science:

GEORGE SARTON

ALEXANDER POGO

Associated Investigators:

W. A. HEIDEL

ELIAS A. LOWE

Department of Meridian Astrometry:

Organized 1907; Lewis Boss, Director 1907-1912.

BENJAMIN BOSS, Director

SHERWOOD B. GRANT

HEROY JENKINS

HARRY RAYMOND

ARTHUR J. ROY

W. B. VARNUM

RALPH E. WILSON

Nutrition Laboratory:

Organized in 1907, opened 1908.

FRANCIS G. BENEDICT, Director

T. M. CARPENTER

V. COROPATCHINSKY

E. L. FOX

Mount Wilson Observatory:

Organized 1904; George E. Hale, Director 1904-1923.

GEORGE E. HALE, Honorary Director
WALTER S. ADAMS, Director
F. H. SEARES, Assistant Director
ALFRED H. JOY, Secretary
A. S. KING, Supt. Physical Laboratory
J. A. ANDERSON
WALTER BAADE
HAROLD D. BABCOCK
THEODORE DUNHAM JR.
FERDINAND ELLERMAN
EDWIN P. HUBBLE

MILTON L. HUMASON
PAUL W. MERRILL
SETH B. NICHOLSON
FRANCIS G. PEASE
EDISON PETTIT
R. S. RICHARDSON
R. F. SANFORD
SINCLAIR SMITH
CHARLES E. ST. JOHN (Retired)
GUSTAF STRÖMBERG
A. VAN MAANEN

Division of Plant Biology:

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923, and reorganized in 1928 as Division of Plant Biology, including Ecology.

H. A. SPOEHR, Chairman
JOHN BELLING (Deceased)
JENS C. CLAUSEN
FREDERIC E. CLEMENTS
F. W. HAASIS
FRANCES L. LONG

DANIEL T. MACDOUGAL (Retired)
H. W. MILNER
FORREST SHREVE
JAMES H. C. SMITH
H. H. STRAIN
GEORGE R. WIELAND (Retired)

Department of Terrestrial Magnetism:

Organized 1904.

J. A. FLEMING, Acting Director
J. E. I. CAIRNES
O. DAHL
F. T. DAVIES (Leave of absence)
C. R. DUVAL
C. C. ENNIS
H. W. FISK
S. E. FORBUSH
O. H. GISH
JOHN W. GREEN
L. R. HAFSTAD
C. HUFF
H. F. JOHNSTON

P. G. LEDIG
A. G. McNISH
WILFRED C. PARKINSON
W. J. PETERS (Retired)
W. J. ROONEY
S. L. SEATON
K. L. SHERMAN
OSCAR W. TORRESON
M. A. TUVE
G. R. WAIT
W. F. WALLIS
F. W. WOOD

Seismological Research:

H. O. WOOD, Research Associate
HUGO BENIOFF

CHARLES F. RICHTER

Investigators at Tortugas Laboratory, Summer 1933:

PAUL BARTSCH, U. S. National Museum
L. R. CARY, Princeton University
H. H. DARBY, Bartol Research Foundation
MYRON GORDON, Cornell University
CASWELL GRAVE, Washington University
E. R. HELWIG, University of Pennsylvania
M. J. KOPAC, University of California
W. H. LONGLEY, Goucher College
C. W. MERRIAM, University of California
PAUL A. NICOLL, Washington University
FERNANDUS PAYNE, Indiana University
P. B. A. POWERS, University of Pennsylvania
F. C. STEWARD, University of Leeds
GEOFFREY TANDY, British Museum (Natural History)
D. H. TENNENT, Bryn Mawr College
J. M. WILSON, Medical College of South Carolina
SHIGEO YAMANOUCI, University of Chicago

Additional Research Associates:

SEBASTIAN ALBRECHT (Dudley Observatory), Astronomy
ERNEST ANDERSON (University of Arizona), Plant Biology
E. B. BABCOCK (University of California), Genetics
I. W. BAILEY (Bussey Institute), Plant Biology
J. BARTELS (Forstliche Hochschule, Eberswalde), Terrestrial Magnetism
R. B. BENNETT (Massachusetts Institute of Technology), Physics
V. BJERKNES (University of Oslo, Norway), Meteorology
G. BREIT (New York University), Physics
J. P. BUWALDA (California Institute of Technology), Paleontology
IAN CAMPBELL (California Institute of Technology), Geology
W. A. CANNON (Stanford University), Biology
W. E. CASTLE (Harvard University), Biology
RALPH W. CHANEY (University of California), Paleobotany
A. H. COMPTON (University of Chicago), Physics
K. T. COMPTON (Massachusetts Institute of Technology), Physics
H. E. CRAMPTON (Columbia University), Biology
L. R. DICE (University of Michigan), Biology
A. E. DOUGLASS (University of Arizona), Ecology
WALTER EDDY (Columbia University), Physiological Chemistry
M. R. HARRINGTON (Southwest Museum), Archaeology
F. A. HARTMAN (University of Buffalo), Physiology
NORMAN E. A. HINDS (University of California), Geology
J. H. JEANS (Royal Society of London), Astronomy
THOMAS H. JOHNSON (Bartol Research Foundation), Physics
REMINGTON KELLOGG (U. S. National Museum), Paleontology
A. E. KENNELLY (Harvard University), Terrestrial Magnetism
ALBERT MANN (U. S. National Museum), Biology
JOHN H. MAXSON (California Institute of Technology), Geology
L. B. MENDEL (Yale University), Physiological Chemistry
R. A. MILLIKAN (California Institute of Technology), Physics
T. H. MORGAN (California Institute of Technology), Biology
FRANK MORLEY (Johns Hopkins University), Mathematics
JAMES G. NEEDHAM (Cornell University), Biology
EARLE B. PHELPS (Columbia University), Physiology
GREENLEAF W. PICKARD, Terrestrial Magnetism
HENRY A. RUGER (Columbia University), Psychology
G. OSCAR RUSSELL (Ohio State University), Physiology
HENRY N. RUSSELL (Princeton University), Astronomy
A. G. SHENSTONE (Princeton University), Physics
H. C. SHERMAN (Columbia University), Nutrition
JOEL STEBBINS (University of Wisconsin), Astronomy
CHESTER STOCK (California Institute of Technology), Paleontology
J. C. STREET (Harvard University), Physics
J. B. SUMNER (Cornell University), Biochemistry
H. U. SVERDRUP (Geofysisk Institut, Bergen, Norway), Terrestrial Magnetism
H. B. VICKERY (Connecticut Agric. Exper. Station), Physiological Chemistry
LEWIS H. WEED (Johns Hopkins University), Anatomy
DAVID WHITE (National Academy of Sciences), Paleontology
R. R. WILLIAMS (Bell Telephone Laboratories), Physiological Chemistry
BAILEY WILLIS (Stanford University), Seismology
CLARK WISSLER (American Museum of Natural History), Archaeology

ORGANIZATION, PLAN AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the endowment fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals, usually in direct association with organized activities of the Institution, may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott,

ARTICLES OF INCORPORATION

Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to

ARTICLES OF INCORPORATION

organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

BY-LAWS OF THE INSTITUTION

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

ARTICLE IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and,

in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

BY-LAWS OF THE INSTITUTION

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES OF THE THIRTY-FOURTH MEETING
OF THE BOARD OF TRUSTEES

ABSTRACT OF MINUTES OF THE THIRTY-FOURTH MEETING OF THE BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 15, 1933. It was called to order at 10 a. m. by the Chairman of the Board, Mr. Root.

Upon roll-call, the following Trustees responded: W. W. Campbell, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Cass Gilbert, Frederick H. Gillett, William Church Osborn, Stewart Paton, John J. Pershing, Henry S. Pritchett, Elihu Root, Theobald Smith, William Benson Storey, James W. Wadsworth jr., and Frederic C. Walcott. The President of the Institution, John C. Merriam, was also present.

The minutes of the thirty-third meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1934 were authorized:

Pension Fund	\$ 60,000
Administration	67,900
Publications (including Division of Publications).....	101,320
Departments and Divisions of Research.....	1,132,263
Minor Grants	107,500
General Contingent Fund	50,000
Special Emergency Reserve Fund.....	30,000
	1,548,983

Balloting for new Trustees to fill vacancies caused by death of John J. Carty and of William S. Thayer resulted in election of Roswell Miller and Frank B. Jewett, of New York.

Mr. Root was re-elected Chairman of the Board of Trustees, Mr. Pritchett was re-elected Vice-Chairman, and Mr. Delano was re-elected Secretary of the Board.

Messrs. Forbes, Paton, and Pritchett were re-elected members of the Executive Committee for a period of three years. Messrs. Pritchett (Chairman), Osborn, and Wickersham were re-elected members of the Finance Committee for a period of three years. Messrs. Delano (Chairman), Ferguson, and Storey were re-elected members of the Auditing Committee for a period of three years.

The meeting adjourned at 12.20 p. m.

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON
FOR THE YEAR ENDING OCTOBER 31, 1933

REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on work of the Institution for the fiscal year ending October 31, 1933, together with provisional recommendation of appropriations for the year beginning January 1, 1934.

In a life devoted to service of the public, Robert S. Brookings made important contribution to formulation of ideals and policy in the Carnegie Institution. He became a member of the Board of Trustees in December 1910, and served continuously until 1929, when his resignation became necessary on account of ill health. To the time of his death, on November 15, 1932, Mr. Brookings continued his interest in critical problems of the Institution. In an exceptional way, his clear mind brought into the perspective of one picture many of the most important principles arising in the fields of economics, government, history, and the more fundamental sciences. This comprehensive view, together

with Mr. Brookings' vision in matters touching organization, and his sound judgment on financial problems, had great value for Carnegie Institution in development of major plans through the past two decades.

In the death of John J. Carty on December 27, 1932, the Institution lost a most earnest advocate in the cause of research and a supporter exceptionally well acquainted with the fundamental problems upon which our program is based. General Carty was elected a Trustee in December 1916, and from 1922 to 1929 served as a member of the Executive Committee.

Although his primary interest was in the physical sciences and engineering, General Carty was also deeply interested in all subjects touching human behavior, and was one of the most ardent supporters of investigation relating to that field. His appreciation of the broader values of research, and his vision of purpose and function of the Institution made him one of the most effective advisers on policy and plans.

William S. Thayer, internationally recognized as an authority on internal medicine and physician-in-chief of the Johns Hopkins Hospital, was elected a Trustee of the Institution in December 1929. His sudden death on December 10, 1932, terminated an association which was becoming increasingly valuable to the Institution. Dr. Thayer's personal experience as an investigator made his view of work undertaken in the Institution exceptionally important, both on problems relating to the biological sciences

and on questions concerning general organization and functioning of research programs.

Henry P. Walcott, of Cambridge, Massachusetts, a pioneer and leader in public health, was elected to the Board of Trustees in 1910. He had deep interest in activities of the Institution, but feeble health prevented his attending meetings regularly and he resigned in December 1924. It is with appreciation of his service in discussion of the broader plans for research that record is made of his relation to work of the Institution, and of his death on November 8, 1932.

The gift of the Eugenics Record Office with adjoining property at Cold Spring Harbor, Long Island, by Mrs. E. H. Harriman in 1918 constitutes one of the most important contributions toward support of research activities in the Institution. Mrs. Harriman's interest led to establishment of this Office in 1910. To the time of her death on November 7, 1932, she continued her interest in the work of this laboratory, and in its possible contribution toward improvement of mankind.

In accepting gift of the Eugenics Record Office, the Executive Committee of the Institution expressed its sense of obligation to maintain researches on this group of problems for the benefit of succeeding generations. Through her support of investigation in this field Mrs. Harriman contributed to a movement for human betterment which is destined to go forward with increasing emphasis through the ages.

When the Department of Economics and Sociology of the Institution was organized in 1903 for the purpose of undertaking studies in American Economic History, Professor Henry W. Farnam, of Yale University, was given charge of the Division of Social Legislation. In 1909, after the death of Dr. Carroll D. Wright, Director of the Department, Professor Farnam served as Chairman of the Board of Collaborators of the Department of Economics and Sociology until the work was discontinued by the Institution in 1916. Due to his belief in the value of these studies, they were continued by an organization known as the Board of Research Associates in American Economic History.

Professor Farnam's leadership and constructive ability made possible the important results relating to this project which have been assembled and published. His death, on September 15, 1933, closed a life devoted to extremely effective economic research.

For institutions established with expectation of a short period of service, social, economic, and political changes may have relatively small significance. In those designed to give continuing and developing service, policies may be altered radically through adjustment to changing social conditions. But the longer programs may rest upon fundamental factors which are either not affected immediately by ordinary changes, or are of such a nature that shift in conditions tends only to increase importance of the undertakings.

In the history of this country, the place of research

among factors touching needs of advancing civilization is illustrated by its relation to the broader features of our economic experience. Abundant development of natural resources has produced great wealth and the advantages which flow from it. The period of harvesting these materials has been followed by one of extraordinary mechanical and industrial growth. At the present moment the natural resources are well known and adjusted to future use. Further advance depends largely upon research, inventive genius, and human organization. New ideas ranging from those arising out of physics, chemistry, and biology on into laws of history, problems of economics, social values, governmental principles, and the more fundamental understanding of human behavior have come to take primary place in classification of our needs.

It is difficult to visualize a situation in which we could retreat from the present position. The needs of civilization can never be met by a static condition in which the generations merely settle down to life at a particular level. One can assume that through coming ages the requirement for increased knowledge with new ideas and their bettered application will grow. Unusual constructive ability arising out of what is known as the scientific interpretation will have an increasingly important part in development and organization of society. The investigational process, both as a means of securing ideas and as a method for learning their application, will naturally and properly take its place as one of the most nearly indispensable of all activities upon which the future well-being of mankind depends.

Under conditions of the present and future, it is essen-

tial that, along with other types of agencies, we have institutions devoted primarily to the broader aspects of research or constructive development. It will not suffice that this phase of human activity be relegated to a place of secondary importance. Certain of the organizations devoted to this work should have sufficient scope as to subject, and adequate breadth in geographic location, to represent the wider picture of investigation.

It is not to be expected that any research institution will cover every special subject, or even every aspect of investigation in any given field. But it is desirable that there be agencies in which the broad view will be clearly expressed, and at the same time the more intensive aspects of specialization be represented. A close relation between the concentrated type of investigation and that characterizing the broader view would be one of the natural requirements of such an institution.

The development of great research programs in the industries is one of the unequivocal evidences that the constructive aspect of activity is humanly important. The tendency in universities to voice the idea that the primary function of these institutions is advancement of knowledge is further indication of belief that the investigational type of activity is a major need.

That by reason of great economic changes an agency set up like the Carnegie Institution, with support by endowment, might gradually fade, and its particular functions be carried on through other types of activities, is one possible way to view the program upon which it has embarked. To the founder of the Institution this organization was not just a satisfactory means of spending a cer-

tain sum of money. The idea as originally stated concerned the importance of continuing and intensifying emphasis upon that attitude of mind that tends in the most effective manner "to expand known forces, to discover and utilize new forces for the benefit of man." In choosing to make investment in a phase of activity that concerned continuing development, Mr. Carnegie initiated a work for which, by reason of the nature of human kind and of the universe in which it resides, we see increasing requirement so long as man exists. Though the emphasis will vary as to subjects, as to needs, and as to manner of application, the attitude of open-mindedness and the research mode of approach will continue to increase in importance.

In periods of emergency shifting conditions may tend to press toward extinction of research and research institutions through financial weakening, and because of emphasis on what may be considered essentials of life. In another view, emergencies present tests of adequacy in research as a method and as to human value of specific ideas for the origin of which it is responsible.

In the type of emergency through which the world is now passing, multiplicity of problems, and the influence of depression as contrasted with the accustomed progressive tendencies of other days, turn attention sharply to our needs for knowledge and for scientific judgment. Whether or no we find immediately the curative and constructive factors required to guarantee the kind of forward movement which mankind hopes to see, no question exists as to the requirement for fundamental and far-reaching knowledge bearing upon an almost infinite number of elements involved in the present situation.

Nor is there doubt as to the necessity for clear interpretation and faithful human application of the information sought.

There was never a larger demand for further information and its human use than at the present moment. That this requirement is in considerable part within the relatively difficult fields of economic, social, and governmental problems seems only to emphasize the importance of such demonstration of the method and approach of research, viewed broadly, as will guarantee advance in consideration of new problems on the basis of full knowledge. Under present conditions the significance of research is destined to have increasing recognition, provided there is opportunity for such expression of the results that they may fit accurately and appropriately into the complex mosaic of human interests, and ultimately attain a place among those elements that concern normal movement in development of life.

Unfortunately the complex mechanisms needed in successful research commonly require concentration such that, with stress placed on work of construction, the results may fail to reach and influence other science, or general human interest, or specific human application. Although original investigation which produces new information is the critical operation upon which the greatest concentration of attention must always focus, it is also true that discovery alone may not represent complete or adequate advancement of knowledge. Recording of results, interpretation of what has been obtained, and satisfactory placing of the materials constitute important elements in the process. Unless care is given to handling of informa-

tion derived from research, there may be waste or loss of real values secured. It is also important to realize that interpretation of such data partakes both of science and of that art through which its expression may be most effective.

What we call the emergency of the moment is in a measure occasion for awakening of interest and that sharpening of vision which can give to the inquiring or constructive attitude of mind, and the products of its effort, a human value not previously recognized. Opportunity for utilization of this mode of approach to knowledge by means of the great variety of activities represented in an institution devoted to the cause of research may, under conditions of the present epoch, bring to realization in an exceptional way the kind of service which Mr. Carnegie visualized for an agency which would continuously devote itself to the cause of "discovery, and the application of knowledge to the improvement of mankind."

Obligations which may be assumed to rest upon an institution of this type, in a situation such as now presents itself, are susceptible of definition only in general terms. But opportunities for practical application will appear as new problems of importance to the community relate themselves to special activities of the institution. Situations are conceivable in which, from the advanced position of newly developed knowledge, interests which concern the country broadly will be discovered by research workers before they are known to the community. In such cases the initiative for action may be taken by investigators. The interests of this Institution and those of the country and of mankind broadly are one, and under conditions of

stress it is important that all possible contribution be made toward aid in the public cause.

In many and unexpected ways new and complex problems of this particular period have shown the need, not only of experts concerned with extremely specialized subjects, but along with these the requirement for investigators who can bring knowledge across the boundaries from one field into another in which it may have relatively high value. Many problems which focus in economics or government, but arise through consideration of special questions in the natural sciences, require this close co-operation of workers in different fields.

In a period of wide uncertainty the maintenance of schedules for activity means not only employment but with this it concerns elements of morale, both in the sense of occupation and with reference to confidence in the value of knowledge and its development.

The present general program of the nation, and in reality of the world, is hopefully described as recovery, but the vision that dominates thought in questions of this nature does not concern merely return to earlier conditions. What we really desire is advance to the stage that should be, or should have been attained. Out of present reorganization activities it is probable that much of the most vital thought relates to what may be recognized as having future value. It is in questions of this nature that the trained investigator may see not infrequently the elements of progress so much desired.

Less clearly tangible than other relations to present and future conditions, but not less critical, is the significance attaching to maintenance of standards in thought and ob-

jectives. Investigation is search for the truth regarding all manner of things in the heavens above and the earth beneath, in the fragmentary details concerning life of past ages, in structure of infinitesimal cells and atoms, in the deeper recesses of minds which we call normal and in those that suffer from various ills. But it is always the truth and its relation to other truth that we seek. One could go far toward demonstrating that an institution dedicated to research would justify its existence abundantly if it did nothing more than bring to the world the significance of this type of work as aiding to give evidence of the value of real things and their true relation to each other. There may be a long gap between the meaning of electrons, nebulae, trilobites and enzymes on the one hand and great economic and political problems as they express themselves in life, but the future will unquestionably show that, wherever we work, full value given to realities, whether they concern the existence and nature of things or purposes of action, affords the largest guarantee of success in what we strive to accomplish.

Vigorous discussion regarding causes of present world complications in social, economic, and governmental relations has served to emphasize the need for such knowledge of history as will make possible the focussing of available information upon critical questions. An understanding of most great human problems requires intimate knowledge of what is happening in many parts of the world, and also of the historical steps involved in development of these situations. Study of the growth or evolution of

**Correlated
Investigations
in
American
History**

conditions and ideas may be looked upon merely as economics, sociology, government, or other special topics. But from another point of view, the successional aspect of events is the peculiar field of research concerned with historical processes and development.

Investigations on the story of the Maya people and their culture in Middle America, as conducted by the Division of Historical Research, illustrates a type of study in which effort is made to focus upon the historical or sequence aspect of the problem information derived from all phases of knowledge bearing upon the question. In earlier annual reports attention has been called to the manner in which, through these studies, effort is made to secure such knowledge of the physical and biological environment and life of the people as is needed for interpretation of the historical succession represented in the ruins.

This plan, worked out through several years of careful study, has gone forward in a most satisfactory manner. In addition to extensive publication on the archæology of major sites, important beginning is made in bringing to record results of studies on various correlated subjects. Following the publication by Dr. Morris Steggerda on Anthropometry of Adult Maya Indians, there has appeared this year an extensive series of papers on the Peninsula of Yucatan grouped around results of the medical survey by Dr. George C. Shattuck. There is also completed and ready for publication an important study by Dr. Robert Redfield on the sociological side, presenting an interesting account of the village of Chan Kom, near Chichen Itzá.

As a statement regarding progress in this most significant historical and scientific research, and its bearing upon problems of the present and the future, there is presented the following quotation from the annual report of Dr. A. V. Kidder, Chairman of the Division of Historical Research of the Institution:

Carnegie Institution's first work in the Maya field was purely archæological. Through exploration, and subsequently by excavation, studies were made of the distribution of Maya remains, and information was gathered regarding the nature of Maya culture at various periods. Progress of the research brought increasing realization of the importance of the rôle played by the Maya in building up aboriginal civilization in Middle America; and it also became obvious that the career of the Maya, were it sufficiently well understood, could be counted upon to provide valuable materials for the comparative study of civilization as a social-evolutionary process. But at the same time it was evident that to be of maximum usefulness for Middle American culture history and particularly for broader comparative purposes, our knowledge of the Maya must be much more comprehensive than we could hope to make it by archæological means alone. For, as was stressed in the above-mentioned reports, the spade of the excavator can recover only factual data, and the interpretation of those data, in terms of the factors motivating and directing human action, can only be accomplished in the light of information as to the physical environment in which the Maya lived, as to their racial and mental make-up, as to their recent history and present social practices. With none of these problems is the archæologist fitted to deal. So assistance was solicited from workers in many non-archæological fields; and there has developed a program of investigation amounting to a general scientific survey of the Maya area.

The recent exhibition in this country of the splendid collection of Mixtec relics obtained by Dr. Alfonso Caso at Monte Alban, near Oaxaca, Mexico, has given to students

of early American cultures an extremely important view of the realities in this interesting stage of history. Although representing researches in a department different from that in which the Carnegie Institution has had the privilege of working in Mexico, the opportunity to see this material seemed so desirable that invitation to bring the collection to Washington was extended to the Government of Mexico jointly by Carnegie Institution and George Washington University. In addition to opportunity to view the Monte Alban Collection, the very effective interpretation by the associates of Dr. Caso has given increased stimulus to study and research, and has advanced interest in the whole subject of early American history.

In the group of departments concerned with animal development and physiological process, the Laboratory for Embryology has continued its contribution toward understanding of the fundamental processes involved. Among important advances significant progress is recorded in studies of movement and function of the chromosomes, the elements representing heredity in the cell. As this investigation proceeds, accumulating evidence indicates that origin of these movements originates in the chromosomes themselves. The chromosomes are not inertly drawn apart as was previously supposed.

Definite progress is also made in study of characteristics of malignant cells, a problem of great significance in relation to all research having to do with types of malignant growth which may become a source of danger in the human body.

In the processes which have to do with the life and destiny of the embryo, much wholly new information has been obtained by study of specimens of precisely known age representing various animals. In another direction the mechanical development in certain aspects of reproduction has become more fully known through research on influence of hormones from the anterior pituitary as they affect contraction of the uterus. It is through studies of this nature, ranging over the whole field of development of tissues, the mechanism of reproduction, and the growth of the embryo in relation to structure of the adult, that we approach gradually to full understanding of development in the individual.

Important aid in connection with the program of the Department of Embryology has been given during the past year through cooperation of the International Cancer Research Foundation, which has made generous contribution to support of certain studies by Dr. Warren H. Lewis on rodent carcinoma. While the problem on which Dr. Lewis is engaged continues as a fundamental research in tissue culture, it is in part from investigations of this nature that we derive critical data bearing upon irregular multiplication of cells, a question which lies at the root of cancer research.

In an extremely interesting series of investigations by Dr. Lewis H. Weed, conducted over a number of years in cooperation with the Carnegie Institution of Washington through the embryological laboratory, important advance has been made in study of relation of change in pressure of the cerebral spinal fluid to blood supply to the brain.

Notable advance has been made in the past year through research both on general principles and on detailed problems in the field of heredity. As this program advances it interlocks in many directions with work of various groups within the Institution, as also in other agencies. Of special importance is the community of interest represented by the Department of Genetics and the many studies in this field carried on by the Division of Plant Biology.

**Heredity and
Environment
in Animal
Biology**

In his most carefully prepared annual report from the Department of Genetics, Dr. C. B. Davenport has presented in concise form a number of aspects of certain critical groups of researches on heredity. One of the most significant questions discussed is that relating to the "gene," a unit within the mass of the chromosomes, those minute elements which have contributed so greatly to advancement of knowledge in studies of heredity in recent years. Dr. Davenport's statement is as follows:

The study of heredity is proceeding ever toward more fundamental phenomena. In Galton's day it was a study of the family incidence of certain traits. The plant experiments of a century ago were, like those of the late Mr. Burbank, concerned with the transfer of characteristics by hybridization, by the uniting of alien germ cells. As biological knowledge grew, the problem of the mechanism of heredity was transferred from the germ cells to the nuclei of the cells and especially to the chromosomes. While biological philosophers had long agreed that there must be a finer unit—the gene—it has been scientifically studied for only about the last twenty years.

Concerning the nature of the gene, diverse views exist. One view is that, though simple, it varies in size in different strains. When the gene is large a "strong" well-developed character arises; when small the character is more weakly expressed. On this view the mutations

in a gene are purely quantitative. Another view regards the gene as made up of gene elements or "genomeres," which may or may not be chemically the same. Still another view is that the gene consists of a large molecule to which the same side-chain of molecular groups is attached several times. As between the quantitative theory of differing factors at the same locus and the various theories that call for a qualitative difference between these factors, the observations of Demerec throw the weight of evidence toward the qualitative theory, inasmuch as the various mutations play qualitatively distinct rôles. From this point of view the gene is a compound molecule, the stripping off of whose molecular groups causes changes partly of a quantitative, partly of a qualitative nature. The analogy of this behavior to that of certain better-studied organic molecules is somewhat close. It is thought most probable that each gene in the cell is a substance that directly or indirectly produces enzymes, each of which stimulates differential growth and development of a specific kind.

The investigation of the gene is of the highest importance not only for an understanding of how the body develops and becomes specialized or differentiated in its different parts, but also for an understanding of the nature of the ultimate living substance. When we understand the structure of the gene we shall know the essential difference between living and non-living matter. The geneticist should shortly be in a position to aid the chemist in getting at the ultimate nature of living matter and especially must both cooperate in the solution of the problem of that fundamental property of the living molecule, namely its capacity for dividing indefinitely with retention of all of its qualities. For upon this property depends all agriculture and animal husbandry—depends all life itself. Before the self-dividing molecule had been evolved, this was a lifeless world; unless it has been evolved in other planets, they are lifeless still. The living, dividing molecule, of which the gene is a special sort, is the great upbuilding agency in a universe that is running down. Its capacity for creation is due to the genes whose ability to increase living matter is limited only by the conditions imposed by the non-living world. For the genes create living matter out of the non-living material, while periodically that which they have created is returned to its source for new generations to feed upon.

Indeed, it is not sufficient that the gene multiply, it must forever change and build up a new and different generation to keep pace with changing cosmic conditions, and, as opportunity arises, to meet those conditions more effectively. Of what makes the gene change we have a conception; but of what makes it divide we have no inkling; we only know division to be its unique and fundamental nature.

Another important series of studies of great scientific and human value in the Department of Genetics concerns the disease known as leukemia in mice. These investigations present some of the most interesting evidence of the influence of environment upon development in organisms. Through the work of Dr. MacDowell, and those associated with him, we see development of the leukemia cell influenced by environment as represented by the animal in which it grows. Such cells transplanted from one animal to another may show marked differences in growth. On the other hand, the environment within the animal to which the cells are transplanted is controlled by heredity.

In another field of investigation in the Department of Genetics significant advances in research have been made through the work of Dr. Oscar Riddle on relation of hormones of the anterior pituitary to various functions of the body. Refinement of the researches by which the substance prolactin was discovered in the past year has continued to increase knowledge of critically important relationships through which certain functions of the body are guided or controlled.

It is through comparison of the many types of investigations such as those that have been described, arising sometimes from study of heredity and sometimes from influence of environment, that we approach understanding

of the complex relationships in nature that control development and maintenance of life.

In connection with investigations at the Eugenics Record Office, Dr. H. H. Laughlin has been engaged for many years upon studies of heredity in the thoroughbred horse. These researches have been correlated with investigations relating to inheritance of mental characteristics in human beings. The horse has mental traits that run parallel with certain of those that have been especially interesting in study of man. Fortunately there are available long-extended and carefully maintained records of achievement in horses, together with data concerning ancestry, so that the story of inheritance as represented in the horse offers unusual opportunity for investigations on heredity.

Although researches on the critical physical elements of heredity in the horse, and other aspects of importance in its biological problems of this nature, have been made, there still remains the extremely difficult task of relating what concerns mental characteristics to biological inheritance. But the fact that the relation of these elements to each other is not yet perfectly understood does not eliminate the value of records obtained in the interesting view of inherited characteristics as developed by Dr. Laughlin.

In addition to facilities available through the Eugenics Record Office of the Institution, generous support of Dr. Laughlin's work has been furnished over a period of ten years by Mr. Walter J. Salmon, whose continued interest in the problem has been of great importance in furtherance of Dr. Laughlin's plans.

In the effort to obtain an understanding of relation between influence of factors in heredity and environment in the differentiation of plants, Dr. Harvey **Environment and Heredity in Plant Biology** M. Hall carried out through the Carnegie Institution an extremely interesting series of studies extending over many years. At the time of his death in 1932 this program of research had been realized through consummation of arrangements for field and laboratory studies and by cooperation of expert investigators in the several fields concerned.

Recognizing the importance of bringing the assembled data to a careful test from the point of view of cytology, genetics, ecology, and taxonomy, Dr. Spoehr, Chairman of the Division of Plant Biology, has concentrated attention of investigators in our own staff and of other institutions on continuation of Dr. Hall's researches. As a result there is now under way in the field and at the laboratory of plant biology in California, a most interesting series of investigations which will, it is hoped, make possible critical determination of values under examination by Dr. Hall.

In connection with the activities planned by Dr. Hall for study of field problems in biology, it is fortunate that before his death there had been established several types of reservations on federal lands which will be of great value in future research on fundamental problems of biology. As one of the last items considered in his research program Dr. Hall worked out with the United States Forest Service arrangements for a reservation in the Mono National Forest, at an elevation of about ten thousand feet in the Sierra Nevada. This very impor-

tant area has been designated by the Forest Service as the Harvey Monroe Hall Natural Area.

In presentation of his annual report for the past year Dr. Spoehr has made an important record relating to conditions that develop in consideration of research problems of the Institution such as those which have been described. In this report Dr. Spoehr has also called attention to the necessity for careful examination at this time of all projects in order to make sure that those which are most critical have opportunity for adequate support. The statement is as follows:

The Division has been most fortunate in having been able to maintain the most important of its research projects during the economic stress of the past few years. This applies particularly to those projects in which valuable collections of living material are involved; final results from these investigations might be greatly affected or permanently lost through a serious interruption in their continuity. Conditions are making necessary the examination of all research projects as to their real scientific significance and the careful scrutiny of the mode of operation and methods employed to achieve the desired aims. Difficult as these adjustments are, if they are not too sudden, they may not be without their compensation in helping to clarify the problems under investigation.

Although associated for many years with the Department of Genetics of the Carnegie Institution in study of problems of heredity, Dr. John Belling, who died on February 27, 1933, was a member of the staff of the Division of Plant Biology during the later years of his life. Through these years the University of California most generously made available quarters in laboratories associated with those of Dr. E. B. Babcock.

**Contribution
of John Belling
to Study of
Heredity**

Dr. Belling's contribution to research on problems of genetics comprises many additions to knowledge of critical materials of heredity. During his last years Dr. Belling concentrated the marvelous technique of which he was master upon study of the gene, to which reference has already been made under the discussion of heredity by Dr. Davenport on page 16. However science may ultimately estimate the exact values of Dr. Belling's work, there can be no doubt that in the broad field of studies on heredity his contribution will always rank as one of the most important during this period in the history of science.

The program of research on seismology upon which the Institution entered in 1921 was initiated as a means "to secure cooperation of all agencies interested and to develop the best possible plan and methods for conduct of the work in the future."

**Theoretical
and Practical
Study of Earth
Movement**

This research was looked upon as a means of following the lead of work already under way for considering the critical problem of earth movement through observation on such activity in progress. The dynamic aspects of geologic science, and questions as to cause of movement, have been among the most intriguing and at the same time some of the most imperfectly known factors in study of the earth.

Under leadership of Dr. Arthur L. Day of the Institution, consideration of the seismological program was taken up by a committee representing the best knowledge and judgment among eminent students in this field. Through cooperation with many individuals and institu-

tions, and with departments of the government, rapid progress was made in defining plans for study of instrument construction. A program was also laid out for research in a region having complex geological structures which are fairly understood, and where from time to time there have been earth movements of such a character that their nature could be interpreted in relation to geological features.

While the activities of the Institution were not directed specifically toward engineering research, ultimate use in that field was one of the special objectives in the program, and the results obtained have been utilized in many important ways.

Location of a central station for seismological research in the southern area of the Pacific Coast region of the United States was made possible by generous cooperation of California Institute of Technology. Substations were made available by other institutions and communities desirous of aiding in advance of knowledge on this subject. California Institute contributed in a most important way through providing the site and a building carefully designed and constructed under guidance of the Advisory Committee in Seismology. California Institute has also cooperated through use of funds for equipment and research. Most significant of all has been the contribution of the Institute through appointment of Dr. Beno Gutenberg as seismologist on the staff of the Institute, and the large service given by its staff members in geology, mathematics, physics, and engineering. In all of these relations the broad and fundamental knowledge of Dr. J. P. Buwalda, of the Institute, on problems of geology

and their bearing on seismology has gone far to make possible close and effective cooperation with members of the Carnegie Institution staff.

As advance of seismological knowledge has made it practicable, the engineering staff of California Institute, in cooperation with seismologists and geologists, has utilized available material for important researches on building problems as they relate to earth movements. Engineering researches on comparable questions have been conducted as independent projects at Stanford University, University of California, and many other institutions of the country.

The knowledge of earth movement obtained in the past year through shocks of relatively heavy intensity has, through cooperation of California Institute and the group working in touch with the Seismological Laboratory at Pasadena, been transmuted quickly into information of large human value. The data secured by this careful search for knowledge as to what actually takes place in seismic activity have had immediate practical use. The general program of investigation as visualized a little more than ten years ago has reached a stage at which the numerous researches now developing rapidly in relation to the Laboratory begin to give us an understanding of activities within the earth such as only true acquaintance with nature can furnish.

In connection with attempt to secure a clear interpretation of the significance of magnetism as a basis for studies of the general problem of magnetic variation over the earth, it has been the policy of the Department of Terres-

**Atomic
Research
in Relation
to Terrestrial
Magnetism**

trial Magnetism to conduct researches in basic physics related to those on the magnetic values of the earth as a unit. Investigations now under way by Dr. Tuve, Dr. Hafstad, and Mr. Dahl have brought extremely interesting results, not only in relation to magnetism, but with reference to function and structure of the atom. The excellent work done by Dr. Tuve through use of a Coolidge type of tube is now being continued by employment of the Van der Graaff method by which at least two million volts have been developed.

During the past year there has been erected for the Department a new building equipped especially for physical researches, and most interesting results are now being secured in bombardment of the atom. With work under way in other laboratories, through cooperation with other investigators, it is hoped that rapid advance will be made toward understanding of certain phases of the problem of magnetism for examination of which the Department was established.

Through the aid of funds made available by the Carnegie Corporation, it has been possible to give a measure of aid to advance of cosmic ray research during the past two years. During the first of these years support was limited to the investigations of Dr. R. A. Millikan and those of Dr. Arthur Compton.

**A Program
of Cosmic
Ray Research**

In 1933 the considerable number of important requests could be met only by a plan for relation of these researches such as would permit cooperation which might reduce the total of expenditures proposed. With the aid of Dr. Milli-

kan, Dr. Compton, and a small committee of members of the Carnegie Institution interested in advancing this plan, it has been possible to arrange types of correlated investigations of special importance at this stage in development of the subject. Of particular significance has been the possibility of making observations over a wide range of latitude and altitude, including also results of observations at low latitude and high altitude such as were possible at the Institution's station for studies in physical problems related to terrestrial magnetism at Huancayo, Peru.

In advance of knowledge through research, the results attained may have value without reference to the means by which they are secured. The product of activity arising from investigation may continue to make its contribution after the physical instruments, the theories, and personalities concerned have disappeared. But this is not the normal situation. Commonly, as researches actually develop, there are great possibilities for influence by the personalities through which results are realized. Also, the method by which a specific contribution is made may be enormously important both in conduct of a particular study and through other types of investigations located in distant fields. The value of such research methods and of their by-products may be especially large for investigators whose interests touch the particular problem under examination. It is therefore important that in the conduct of researches opportunity be open for cooperation with other investigators in related or even in distant fields of study.

At the same time it is important to recognize the influ-

ence of such developing researches upon those who are beginning with interest and enthusiasm to take up the field of studies involved. Such contacts mean the passing on of the torch as it is represented in actual knowledge, and more especially through point of view and inspirational value.

The influence of personal relationships in stimulation and advance of research is recognized as of great significance in educational institutions. Its value is not less in the work of an agency such as this Institution devoted specifically to investigation. It is important that, so far as possible, opportunity be given for cooperation which will aid research in fields related to those in which the Institution is engaged. It is of course true that the particular types of influence represented will in general concern themselves principally with subject, material, and modes of approach illustrated in an important way in the special kinds of research carried on in this Institution.

With full appreciation of the value in such types of cooperation for advancement of research in the broadest way, departments of the Institution have, over the years, given increasing aid to other agencies and institutions so far as our facilities have made this possible. During the past year a small group of departments of the Institution has been able collectively to give cooperative aid for considerable periods to approximately sixty persons.

In the budget plan of 1934, the only section which presents a slightly higher figure than in 1933 is that for **Publication Program** Publications. In part this difference represents recognition of special responsibility for a period such as the present emergency in which it is

important not only to aid in recording of data from research, but with this to help in the interpretation of scientific materials. It is believed that by this means we may assist in making more clear the significance of investigation as a factor influencing the possibilities of forward or constructive movement at a time when clear vision is especially important.

Continuing careful supervision of the sources of income of the Institution by the Finance Committee has made it possible to maintain for 1934 a budget program in general comparable to that in 1932 and 1933. A plan involving setting up of a special reserve which might be used to cover possible losses of income, along with the maintenance of a strong position with reference to the Contingent Fund, and modest increase of the Emergency Reserve Fund, made possible the budgetary program of 1933.

For 1934 a plan comparable to that of 1933 has been worked out with improved safeguards against possible losses, and with slight retrenchment in nearly all special budgets. Cooperation of the departments has permitted limiting the financial program to a somewhat narrower range of operations than in recent years. It will, however, be feasible to carry on the work of the Institution without serious curtailment of principal activities.

While budget reduction has limited certain types of work, especially those which have to do with field operations and the securing of new data, the result of budgetary revision has not reduced the productivity of the Institution, nor has it affected quality of the work.

FINANCIAL STATEMENT

The sources of funds available for expenditure during the fiscal year (including appropriations made by the Trustees, December 9, 1932, and revertments and transfers made during the year), the amounts allotted by the Executive Committee during the year, and the balances unallotted at the end of the year are shown in detail in the table.

**Financial
Statement
for Fiscal Year
1932-1933**

Financial statement for fiscal year ending October 31, 1933

	Balances unallotted Oct. 31, 1932	Trustees' appropri- ation Dec. 9, 1932	Revert- ments and transfers Nov. 1, 1932, to Oct. 31, 1933	Total available 1933	Executive Committee allotments 1933	Transfers by Execu- tive Com- mittee	Unallotted balances Oct. 31, 1933
Large Grants:							
Embryology.....		\$73,670	\$1,092	\$74,762	\$74,762		
Genetics.....		137,970	5,580	143,550	143,550		
Geophysical Laboratory.....		171,472	1,000	172,472	172,472		
Historical Research.....		159,100	6,195	165,295	165,295		
Tortugas Laboratory.....		14,000		14,000	14,000		
Meridian Astrometry.....		33,320		33,320	33,320		
Mt. Wilson Observatory.....		230,670		230,670	230,670		
Nutrition Laboratory.....		48,980		48,980	48,980		
Plant Biology.....		112,342	5,550	117,892	117,892		
Terrestrial Magnetism.....		193,290	6,000	199,290	199,290		
Minor Grants.....	\$1,165.46	101,000	11,896.70	114,062.16	113,975		\$87.16
Publications.....	3,990.39	97,420	10,993.82	112,404.21	97,319.97		15,084.24
Administration.....		67,960	1,400	69,360	69,360		
Pension Fund.....		60,000		60,000	60,000		
General Contingent Fund....	60,303.96	50,000	55,147.05	165,451.01	5,326.85	\$41,119.50	119,004.66
Sp'. Emer., Reserve Fund....		30,000		30,000	30,000		
	65,459.81	1,581,194	104,854.57	1,751,508.38	1,576,212.82	41,119.50	134,176.06

CARNEGIE INSTITUTION OF WASHINGTON

The aggregate of receipts from interest on bond investments and bank deposits, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution are shown below; the grand total of these to date is \$83,453,508.23.

Aggregate of financial receipts

Year ending Oct. 31	Interest on bonds and bank deposits	Sales of publications	Refunds on grants	Miscellaneous items	Total
1902	\$250,009.70			\$1,825.52	\$251,835.22
1903	505,867.10	\$2,286.16		101.57	508,254.83
1904	533,004.26	2,436.07	\$999.03		536,439.36
1905	525,698.59	3,038.95	200.94	150.00	529,088.48
1906	527,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	522,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	567,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	614,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	610,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911	989,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,131,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,149,670.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,164,382.80	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,168,263.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916	1,184,001.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917	1,201,111.35	11,921.35	32,950.22	179,611.97	1,425,594.89
1918	1,230,891.47	9,921.00	39,833.23	255,354.60	1,536,000.30
1919	1,251,141.98	12,837.58	53,549.98	214,498.99	1,532,028.53
1920	1,272,000.28	18,393.79	4,088.63	176,249.81	1,470,732.51
1921	1,282,652.47	16,684.51	4,068.69	210,518.96	1,513,924.63
1922	1,287,525.61	14,081.84	9,395.66	34,527.38	1,345,530.49
1923	1,306,828.85	13,841.76	9,739.17	1,720,808.90	3,051,218.68
1924	1,308,556.56	11,994.21	18,663.38	409,712.28	1,748,926.43
1925	1,379,281.51	13,680.74	14,315.03	825,156.17	2,232,433.45
1926	1,356,213.02	14,039.02	44,766.64	167,898.35	1,582,917.03
1927	1,385,436.33	10,032.42	19,049.80	1,814,461.93	3,228,980.48
1928	1,715,492.49	10,924.25	31,144.42	26,068,636.68	27,826,197.84
1929	1,593,667.77	8,925.91	110,724.28	6,367,398.68	8,080,716.64
1930	1,644,909.66	9,468.94	61,767.38	1,922,049.30	3,638,195.28
1931	1,682,548.03	8,482.73	30,359.12	2,213,749.06	3,935,138.94
1932	1,707,165.98	5,286.23	25,304.41	1,240,511.49	2,978,268.11
1933	1,646,861.18	4,414.92	35,335.81	1,632,359.06	3,318,970.97
Total...	35,696,948.84	311,439.39	581,772.05	*46,863,347.95	83,453,508.23

* Of this amount \$39,538,800.32 came from the sale of bonds; \$52,015.74 from the Colburn Estate; and \$7,162,031.24 from the Carnegie Corporation of New York.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be classified

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under five heads: (1) Investments in bonds; (2) large projects; (3) minor grants and payments from Pensions, Insurance, and General Contingent Funds; (4) publications; (5) administration. The following table shows the actual expenditures under these heads for each year since the foundation of the Institution.

Aggregate of expenditures

Year end- ing Oct. 31	Purchase of bonds	Large projects	Minor grants and pay- ments from Special Funds	Publica- tions	Adminis- tration	Total
1902	.....	.....	\$4,500.00	.....	\$27,513.00	\$32,013.00
1903	\$100,475.00	.....	137,564.17	\$938.53	43,627.66	282,605.36
1904	196,159.72	\$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	427,941.40	83,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	454,609.75	72,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914	861,864.23	817,894.52	107,507.55	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	502,254.05	695,813.07	100,746.13	62,884.61	48,766.29	1,410,464.15
1918	528,565.55	693,780.00	170,470.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	203,810.84	68,964.23	55,742.83	1,612,602.01
1920	464,279.57	876,437.28	159,633.49	95,933.10	68,739.90	1,665,023.34
1921	109,390.25	981,186.46	171,895.22	81,388.33	58,730.11	1,402,590.37
1922	50,431.05	975,149.20	192,325.46	96,227.01	56,405.15	1,370,537.87
1923	1,715,537.72	930,395.95	232,344.69	89,402.06	63,493.46	3,031,173.88
1924	440,921.24	939,739.67	230,291.90	87,790.74	65,076.47	1,763,820.02
1925	861,583.20	979,615.36	225,307.45	103,531.67	67,266.71	2,237,304.39
1926	178,817.80	1,060,525.36	254,977.20	84,526.23	65,871.48	1,644,718.07
1927	1,623,071.17	1,164,136.05	258,634.17	85,221.42	67,358.11	3,198,420.92
1928	26,010,438.19	1,208,942.20	281,308.76	93,571.02	73,052.60	27,667,312.77
1929	6,428,356.99	1,341,868.84	324,121.39	95,164.52	69,549.41	8,259,061.15
1930	1,864,870.66	1,264,258.33	274,811.52	113,254.12	73,437.13	3,590,631.76
1931	2,157,884.88	1,301,547.21	288,786.36	113,094.11	76,055.89	3,937,368.45
1932	1,214,321.43	1,320,697.90	260,199.37	125,921.05	73,898.71	2,995,038.46
1933	1,598,365.56	1,225,005.80	227,258.93	88,596.12	70,725.95	3,209,952.36
Total	49,540,888.11	24,277,185.28	5,366,979.67	2,110,998.18	1,749,449.03	83,045,500.27

CARNEGIE INSTITUTION OF WASHINGTON

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings and equipment of departmental establishments, the following sums have been expended since the foundation of the Institution:

Real Estate and Equipment, Original Cost

Administration (October 31, 1933):

Washington, D. C.

Building, site and equipment	\$403,546.54
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Division of Plant Biology (September 30, 1933):

Palo Alto, Calif.

Buildings and grounds.....	\$157,903.63	
Laboratory.....	46,895.04	
Library.....	23,032.71	
Operating appliances.....	23,617.92	
	<hr/>	251,449.30

Department of Embryology (September 30, 1933):

Baltimore, Md.

Library.....	2,896.68	
Laboratory.....	12,393.14	
Administration.....	6,661.08	
	<hr/>	21,950.90

Department of Genetics (September 30, 1933):

Cold Spring Harbor, Long Island, N. Y.

Buildings, grounds, field.....	287,554.10	
Operating.....	26,053.07	
Laboratory apparatus.....	21,084.52	
Library.....	38,863.27	
Archives.....	45,488.90	
	<hr/>	419,043.86

Geophysical Laboratory (September 30, 1933):

Upton St., Washington, D. C.

Building, library, operating appliances.....	214,505.53	
Laboratory apparatus.....	140,261.67	
Shop equipment.....	15,314.63	
	<hr/>	370,081.83

Division of Historical Research (September 30, 1933):

Tower Bldg., Washington, D. C.

Operating.....	12,505.58	
Library.....	7,140.96	
	<hr/>	19,646.54

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Tortugas Laboratory (September 30, 1933):

Tortugas, Fla.

Vessels.....	\$30,930.43	
Buildings, docks, furniture and library.....	12,130.86	
Apparatus and instruments.....	9,322.55	
	<hr/>	\$52,383.84

Department of Meridian Astrometry (September 30, 1933):

Albany, N. Y.

Apparatus and instruments.....	4,846.84	
Operating.....	5,266.68	
	<hr/>	10,113.52

Nutrition Laboratory (September 30, 1933):

Boston, Mass.

Building, office, library and shop	131,696.71	
Laboratory apparatus.....	36,054.11	
	<hr/>	167,750.82

Mount Wilson Observatory (August 31, 1933):

Pasadena, Calif.

Buildings, grounds, road and telephone lines.....	202,474.64	
Shop equipment.....	45,855.44	
Instruments.....	665,262.58	
Furniture and operating appliances.....	196,216.92	
Hooker 100-inch reflector.....	606,181.53	
	<hr/>	1,715,991.11

Department of Terrestrial Magnetism (September 30, 1933):

Broad Branch Road, Washington, D. C.

Building, site and office.....	223,724.21	
Survey equipment.....	95,246.51	
Instruments, laboratory and shop equipment....	165,889.62	
	<hr/>	484,860.34
		<hr/>
		3,916,818.60

PUBLICATIONS

Sales of Publications and Value of those on Hand Amounts received from purchases of the Index Medicus, from sales of the Year Book, and from sales of all other publications for each year since the foundation of the Institution are shown in the table below.

Table showing sales of publications

Year	Index Medicus	Year Book	Miscellaneous books
1903.....	\$2,256.91	\$29.25	.....
1904.....	2,370.47	52.85	\$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50.55	10,356.64
1922.....	5,774.59	59.25	8,248.00
1923.....	5,777.46	70.10	7,994.20
1924.....	4,533.68	31.00	7,429.53
1925.....	5,636.25	25.00	8,019.49
1926.....	5,728.31	41.40	8,269.31
1927.....	1,650.65	59.67	8,322.10
1928.....	887.85	87.80	9,948.60
1929.....	433.70	41.74	8,450.47
1930.....	363.65	127.85	8,977.44
1931.....	574.30	159.38	7,749.05
1932.....	119.35	80.60	5,086.28
1933.....	50.20	69.89	4,294.83
Total.....	111,559.50	1,971.94	197,907.95

At the end of the fiscal year there are on hand 82,095 volumes of miscellaneous publications and Year Books, having a sale value of \$250,318.60, also 1428 complete volumes of the Index Medicus which together with miscellaneous numbers

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have a value of \$14,484.75. Publication of the Index Medicus was taken over by the American Medical Association in 1927.

Statistics on Publications

The data furnished in the following table are of statistical interest in respect to the work of publication of the Institution. 652 volumes, which embrace a total of 192,184 pages of printed matter, have thus far been issued.

Statistics of publications

Year	Number of volumes issued	Number of octavo pages	Number of quarto pages	Total number of pages
1902.....	3	46	.....	46
1903.....	3	1,667	.....	1,667
1904.....	11	2,843	34	2,877
1905.....	21	3,783	1,445	5,228
1906.....	19	3,166	1,288	4,454
1907.....	38	6,284	3,428	9,712
1908.....	28	4,843	2,485	7,328
1909.....	19	3,695	1,212	4,907
1910.....	29	3,274	4,831	8,105
1911.....	30	5,062	1,670	6,732
1912.....	23	3,981	2,044	6,025
1913.....	29	6,605	2,752	9,357
1914.....	23	4,978	1,934	6,912
1915.....	23	4,686	1,466	6,152
1916.....	35	9,478	2,430	11,908
1917.....	21	4,464	2,691	7,155
1918.....	17	3,073	1,120	4,193
1919.....	29	5,834	2,431	8,265
1920.....	23	3,962	3,710	7,672
1921.....	18	4,068	1,398	5,466
1922.....	24	4,566	2,039	6,605
1923.....	20	6,459	604	7,063
1924.....	17	4,665	834	5,499
1925.....	24	3,970	1,277	5,247
1926.....	14	4,552	850	5,402
1927.....	17	4,520	2,089	6,609
1928.....	15	4,495	1,044	5,539
1929.....	12	4,938	452	5,390
1930.....	15	4,096	844	4,940
1931.....	14	4,017	1,343	5,360
1932.....	16	2,155	2,588	4,743
1933.....	22	4,256	1,370	5,626
Total...	652	138,481	53,703	192,184

The publication of 24 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of \$47,650. The following list gives the titles and names of authors of the publications issued. It includes 22 volumes, with an aggregate of 4256 octavo pages and 1370 quarto pages. Twelve additional volumes are now in press.

**Publications
Authorized
and Issued
During Year**

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- No. 299. Burnett, Edmund C. Letters of Members of the Continental Congress. Octavo, vol. VI: March 1781 to December 1782. liii+599 pages.
- No. 374. Catterall, Helen T. Judicial Cases concerning American Slavery and the Negro. Octavo, vol. III: Cases from the Courts of Georgia, Florida, Alabama, Mississippi and Louisiana. viii+758 pages.
- No. 409. Donnan, Elizabeth. Documents Illustrative of the History of the Slave Trade to America. Octavo, vol. III: New England and the Middle Colonies. xiii+553 pages.
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- This book contains the following papers:
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Thomas H. Johnson, Research Associate

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Remington Kellogg, Research Associate

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R. A. Millikan, Research Associate

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T. H. Morgan, Research Associate

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REPORT OF THE PRESIDENT, 1933

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J. G. Needham, Research Associate

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Henry A. Ruger, Research Associate

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H. C. Sherman, Research Associate

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J. B. Sumner, Research Associate

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REPORT OF THE EXECUTIVE COMMITTEE

REPORT OF THE EXECUTIVE COMMITTEE

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1933.

During this year the Executive Committee held seven meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 9, 1932, the members of the Executive Committee met and organized by the election of Mr. Pritchett as Chairman for 1933.

A full statement of the finances and work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted herewith. Continuing attention has been given both by the Executive Committee and the Finance Committee to the question of loss of income due to existing economic conditions. Budget recommendations for next year are based upon opinion of these Committees with respect to improved safeguards against possible losses, and necessary retrenchment in expense.

The Board of Trustees, at its meeting of December 9, 1932, appointed Leslie, Banks and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1933. The report of the Auditor, including a balance-sheet showing assets and liabilities of the Institution on October 31, 1933, is submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

Vacancies existing in membership of the Board of Trustees have been caused by death of William S. Thayer on December 11, 1932 and of John J. Carty on December 27, 1932. Nominations to fill these vacancies have been

CARNEGIE INSTITUTION OF WASHINGTON

requested in accordance with provisions of the By-Laws, and such nominations will be submitted to the Board at its annual meeting on December 15, 1933.

Tenures of office of the following officers of the Board of Trustees will expire at the annual meeting on December 15: Mr. Root, Chairman of the Board; Mr. Pritchett, Vice Chairman of the Board, and Mr. Delano, Secretary of the Board. Tenures of office of Messrs. Forbes, Paton and Pritchett as members of the Executive Committee, of Messrs. Pritchett, Osborn and Wickersham as members of the Finance Committee, and of Messrs. Delano, Ferguson and Storey as members of the Auditing Committee also expire at the meeting of December 15.

HENRY S. PRITCHETT, *Chairman*
FREDERIC A. DELANO
W. CAMERON FORBES
CASS GILBERT
JOHN C. MERRIAM
STEWART PATON
ELIHU ROOT
FREDERIC C. WALCOTT

November 15, 1933.

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1933

RECEIPTS		DISBURSEMENTS	
<i>Interest from—</i>		<i>Investment.....</i>	<i>.....(*)</i>
<i>Securities and Bank Balances.....</i>	\$35,696,948.84		\$49,540,888.11
<i>Colburn Fund.....</i>	52,015.74	<i>Pension Fund.....</i>	589,015.51
<i>Sales of Publications.....</i>	311,439.39	<i>Insurance.....</i>	91,221.83
<i>Revertments.....</i>	605,337.41	<i>General Contingent Fund.....</i>	73,183.74
<i>Pension Fund.....</i>	62,760.66	<i>Special Emergency Reserve Fund.....</i>	121,165.13
<i>Insurance Fund.....</i>	10,527.57	<i>Special Reserve Fund for Administration Bldg. Additions.....</i>	1,323.53
<i>Special Reserve Fund (Rentals).....</i>	6,962.10	<i>Grants</i>	
		<i>Large.....</i>	\$24,277,185.28
		<i>Minor.....</i>	4,341,069.93
<i>Redemption and Sale of Bonds.....</i>	39,538,800.32	<i>Publication.....</i>	2,110,998.18
<i>Carnegie Corporation of N. Y.....</i>	7,162,031.24	<i>National Research Council.....</i>	150,000.00
<i>Miscellaneous.....</i>	6,684.96	<i>Administration.....</i>	1,749,449.03
	83,453,508.23	<i>Cash in Banks.....</i>	83,045,500.27
			408,007.96
			83,453,508.23

(*) Including Administration Building, \$309,915.69, and Collection Charges.

REPORT OF AUDITORS

New York, November 18, 1933

TO THE BOARD OF TRUSTEES,
Carnegie Institution of Washington,
Washington, D. C.

DEAR SIRs:

We have audited the accounts of the Carnegie Institution of Washington for the fiscal year ended October 31, 1933.

The Investments, shown on the Balance Sheet at cost, were verified by physical inspection and all Income has been accounted for. Appropriations and allotments were checked with certified copies of the Minutes of the Institution.

The Cash in banks was confirmed by the depositories and the Cash on hand was counted.

Real Estate and Equipment are carried at cost.

The books of the various departments are audited by the Bursar, and we have included his figures in the annexed Balance Sheet without examination by us.

WE HEREBY CERTIFY that, in our opinion, the Balance Sheet annexed hereto correctly states the financial condition of the Institution at October 31, 1933.

Very truly yours,

LESLIE, BANKS & Co.,
Accountants.

Copies of the Financial Statement, certified by the auditor in the above report, follow on pages 68 to 74.

Balance Sheet, October 31, 1933

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REPORT OF AUDITORS

Receipts and Disbursements for Year Ending October 31, 1933

RECEIPTS		DISBURSEMENTS	
<i>Interest from—</i>		<i>Investment</i>	
Securities.....	\$1,645,590.95	Securities.....	\$1,576,894.60
Bank Balances.....	1,270.23	Accrued Interest.....	21,470.96
<i>Sales of Publications</i>		<i>Pension Fund.....</i>	<i>64,531.22</i>
Index Medicus.....	50.20	<i>Insurance Fund.....</i>	<i>4,000.94</i>
Year Book.....	69.89	<i>General Contingent Fund.....</i>	<i>7,364.31</i>
Miscellaneous Books.....	4,294.83	<i>Special Emergency Reserve Fund.....</i>	<i>11.89</i>
<i>Reversions</i>		<i>Special Reserve Fund for Administration Building Additions.....</i>	<i>428.65</i>
Large Grants—		<i>Grants</i>	
Departments.....	12,677.20	Large.....	1,225,005.80
Contributions—		Minor.....	150,921.92
National Research Council.....	1,250.00	<i>Publication</i>	
California Institute Technology.....	12,599.88	General Publication.....	55,086.43
A. H. Compton.....	1,000.00	Catalogues, Calendars, etc.....	954.27
International Cancer Research Foundation.....	900.00	Shipping expenses.....	7,942.86
Minor Grants.....	28,427.08	Division of Publications.....	24,612.56
Publication.....	1,141.90	<i>Administration</i>	
Administration.....	4,103.68	Trustees.....	2,518.25
Unappropriated Fund.....	1,182.75	Executive Committee.....	3,791.52
<i>Pension Fund.....</i>	<i>480.40</i>	Salaries.....	46,775.06
<i>Insurance Fund.....</i>	<i>372.35</i>	Surety, post, tel. & tel.....	2,603.97
<i>Special Reserve Fund (Rentals).....</i>	<i>2,497.60</i>	Printing, Paper.....	1,157.30
<i>Redemption and Sale of Securities.....</i>	<i>1,536,529.11</i>	Office expenses.....	6,014.65
<i>Carnegie Corporation of N. Y.....</i>	<i>87,750.00</i>	Equipment.....	222.86
<i>Miscellaneous.....</i>	<i>.....</i>	Building maintenance.....	5,090.64
<i>Balance, Oct. 31, 1932.....</i>	<i>3,318,970.97</i>	Lectures and Exhibits.....	2,551.70
	298,989.35	<i>Cash in Banks Oct. 31, 1933.....</i>	<i>70,725.95</i>
	3,617,960.32		3,209,952.36
			408,007.96
			3,617,960.32

CARNEGIE INSTITUTION OF WASHINGTON

Schedule of Securities

Aggregate— Par or Nominal Value	Description	Registered		Matur- ity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
Railways						
\$500,000	A. T. & S. Fe 1st & ref. 4½s.			1962	M-S	\$498,750.
43,000	" " " conv. 4s.			1955	J-D	39,022.50
50,000	A. T. and S. Fe gen. 4s.	*		1995	A-O	50,056.25
75,000	B. & O. R. R. 1st Mtg. 4s.			1948	A-O	64,937.50
150,000	B. and O. R. R. gen. ref. 5s (\$100,000 fully reg.)	*		1995	J-D	153,625.
200,000	Boston & Maine 1st 5s.			1967	M-S	195,812.50
100,000	Canadian National Ry. Co. 5s.			1969	J-J	98,500.
100,000	" " " 4½s.			1956	F-A	98,000.
160,000	Canadian Pac. Col. Trust 5s.			1954	J-D	159,710.07
50,000	Canada So. con. 5s.		*	1962	A-O	49,021.50
175,000	Ches. & Ohio gen. 4½s.			1992	M-S	174,062.50
75,000	Ches. & Ohio Ry. ref. and imp. 4½s. Series A			1993	A-O	72,625.
100,000	" " " " " 4½s. Series B			1995	J-J	98,250.
100,000	Ches. & O. R. R., Eq. Tr., Series 1929				M-N	96,825.50
50,000	Cent. Pac. Ry. 1st ref. 4s.	*		1949	F-A	48,250.
180,000	Chicago B. & Q. R. R. gen. 4s.	*		1958	M-S	169,501.25
200,000	Chicago B. and Q. Ill. Div. 4s.			1949	J-J	200,000.
35,000	Chicago M. St. P. & P. 5s.			1975	F-A	31,853.50
189,000	Chicago, Ind. & L. 1st & gen. 5s.			1966	M-N	189,461.25
140,000	Chicago M. St. P. & P. conv. adj. 5s.			2000	A-O	127,414.50
234,000	Chicago M. and St. P. Ry. gen. 4½s (\$5,000 fully registered)	*		1989	J-J	227,162.50
120,000	Chicago and N. W. Ry. gen. 3½s.	*		1987	FMAN	100,300.
200,000	Chicago & N. W. Ry. gen. 4½s.			1987	M-N	210,000.
300,000	Chicago, R. I. & P. Ry. 4½s.			1952	M-S	282,362.50
100,000	Chicago U. Station 6½s.			1963	J-J	114,266.50
100,000	Clev. C. C. & St. L. Ry., ref. and imp. 4½s.			1977	J-J	99,272.50
100,000	Clev. C. C. & St. L. Ry. gen. 4s.			1993	J-D	78,906.25
50,000	Clev. U. Term. 1st sink. 5½s.			1972	A-O	51,612.50
250,000	Elgin J. & E. Ry. Eq. 5s.	*			J-J	250,000.
120,000	" " " 6s.	*			A-O	120,000.
300,000	Erie R. R. gen. 4s.			1996	J-J	242,937.50
69,000	Gt. Nor. 1st ref. 4½s.	*		1961	J-J	69,053.25
125,000	Gt. Nor. Ry. gen. 4½s.			1977	J-J	122,656.25
165,000	" " " 5s.			1973	J-J	174,712.50
300,000	Ill. Cent. R. R., Joint 5s.			1963	J-D	311,291.50
121,000	Ill. Cent. R. R. ref. 4s.	*		1955	M-N	108,677.50
220,000	Ill. Cent. Eq., Trust, 4½s.				A-O	211,687.79
200,000	Kan. City Term. 1st 4s.			1960	J-J	179,728.76
200,000	Kan. City, F. S. & M. Ry. ref. 4s.			1936	A-O	187,250.
325,000	Lehigh and L. E. 4½s.	*		1957	M-S	331,568.30
100,000	Lehigh V. H. Term. Ry. 1st 5s.			1954	F-A	104,750.
50,000	Long Island ref. 4s.	*		1949	M-S	48,285.
250,000	Louisville & N. R. R. 1st & ref. 4½s.			2003	A-O	249,125.
200,000	Mo. Kan. & T. 1st 4s (\$100,000 reg. prin.)		*	1990	J-D	165,206.26
213,000	Mo. Pac. R. R. Co. 1st and ref. 5s.		*	1977	M-S	212,762.50
200,000	Mo. Pac. R. R., Eq. Trust, 4½s.				M-N	192,206.79
150,000	Mobile and O. R. R., ref. and imp. 4½s (Certificate of Deposit)			1977	M-S	145,750.
55,000	Morris & Essex R. R. Co., Constr. Mtg. 4½s.			1955	M-N	52,937.50
175,000	N. Y. Cent. R. R. ref. & imp. 5s.			2013	A-O	186,906.25
50,000	N. Y. W. and Boston 1st 4½s.	*		1946	J-J	49,187.50
70,000	Norfolk & W. Joint 4s.			1941	J-D	64,925.
100,000	Nor. Pac. ref. and imp. 6s.			2047	J-J	102,187.50
50,000	" " gen. lien 3s.	*		2047	FMAN	33,101.25
51,000	Ore. Short Line con. 5s. (\$49,000 reg. prin.)		*	1946	J-J	49,883.25
310,000	Ore. Wash. R. & N. 1st ref. 4s (\$50,000 fully registered)	*		1961	J-J	274,272.50
80,000	Pa. R. R. Co. gen. 4½s.	*		1965	J-D	80,900.
125,000	" " con. 4½s.	*		1960	F-A	130,703.13
100,000	Pitts. C. C. & St. L. 5s.		*	1975	A-O	99,637.50
42,000	Pitts. Shawmut & Nor. 4s (Ctf. Dep.)			1952		4,200.
100,000	So. Pac. 1st ref. 4s.	*		1955	J-J	92,148.75
200,000	So. Pac. convertible 4½s.			1969	M-N	180,000.
350,000	So. Rwy. Co. 1st con. 5s (\$100,000 registered as to principal)		*	1994	J-J	362,531.25
45,000	St. Paul Union D. 1st & ref. 5s.			1972	J-J	48,150.
225,000	St. Louis-S. F., prior lien 4s.			1950	J-J	203,431.25
32,000	Term. R. R. Ass'n, 1st. Mtg., 4½s.			1939	A-O	30,400.
230,000	Term. R. R. Assn. 4s (\$12,000 reg. prin.)	*		1953	J-J	208,984.25
210,000	Texas & Pac. Ry., gen. and ref. 5s.			1977	A-O	213,882.50
2,084,000	Union R. R. deb. 6s.	*		1946	J-D	2,084,000.
140,000	Union Pac. 1st lien and ref. 4s.	*		2008	M-S	128,722.50
150,000	Union Pac. R. R. 4s.			1968	J-D	133,031.25
200,000	Va. Ry. Co. 1st 5s (\$100,000 registered as to principal)		*	1962	M-N	206,535.50
200,000	Wabash Ry., ref. and gen. 5s.			1976	F-A	203,250.
200,000	Western Md. R. R. 1st 4s.			1952	A-O	162,100.
62,000	Wash. Term. Co. 1st 3½s (\$25,000 fully reg.)	*		1945	F-A	53,728.75
13,070,000	Railway Sub-Total					12,646,947.85

REPORT OF AUDITORS

Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int	Princ. Only			
	<i>Public Utility and Municipal</i>					
\$200,000	Ala. Power Co. 1st ref. 5s.....			1951	J-D	\$197,250.
100,000	Ala. Power Co. 1st & ref. 5s.....			1968	M-S	99,656.25
125,000	Am. Tel. & Tel. Co. sink. deb. 5½s (\$110,000 registered as to principal).....		*	1943	M-N	130,260.62
220,000	Am. Tel. & Tel. Co. deb. 5s (\$100,000 regis- tered as to principal).....		*	1960	J-J	225,866.67
310,000	Am Tel. & Tel. Co. deb. 5s.....			1965	F-A	311,012.50
300,000	Appalachian Electric Power Co. 1st ref. 5s (\$50,000 registered as to principal).....		*	1956	M-N	296,125.
300,000	Ark. P. & L. Co. 5s.....			1956	A-O	292,312.50
50,000	City of Baltimore, Gen. Imp. 5s.....	*		1945	M-S	48,000.
172,000	Bell Tel. Co. of Canada 1st 5s.....			1955	M-S	177,267.50
100,000	" " " " 4½s.....			1957	J-D	101,125.
300,000	Birmingham E. Co., 1st ref. 4½s.....			1968	M-S	283,056.25
75,000	Blackstone Valley Gas & E. 5s.....			1952	A-O	70,781.25
50,000	Brooklyn Edison Co., gen. mtg. 5s.....			1952	J-J	48,375.
50,000	City of Buffalo, 6s.....			1943	M-N	51,375.
300,000	Carolina Power & L. Co. ref. 5s (\$25,000 reg- istered as to principal).....		*	1956	A-O	302,298.75
160,000	Cedar R. Mfg. & P. Co. 1st sink. 5s (\$100,000 registered as to principal).....		*	1953	J-J	159,319.65
235,000	Cincinnati Gas. & E. 1st 4s.....			1968	A-O	210,016.16
50,000	City of Cleveland Water Works, 5½s.....			1967	M-N	52,984.60
380,000	Columbia Gas and Elec. Corp., deb. 5s.....			1961	J-J	379,762.50
299,000	Columbus Rwy., P. & L. 4½s.....			1957	J-J	284,909.62
95,000	Comm. Edison 1st coll. 4½s.....			1956	A-O	93,407.43
48,000	" " " " Mtg. 4s.....			1981	M-S	37,940.49
83,000	" " " " 4½s.....			1957	J-J	74,397.50
60,000	" " " " 5½s.....			1962	J-D	55,650.
60,000	Consolidated Gas Co. of N. Y. deb. 5s.....			1957	J-J	56,250.
100,000	Detroit Edison gen. ref. 5s.....		*	1955	J-D	99,942.50
150,000	Detroit Edison gen. ref. 5s.....			1962	F-A	155,825.
325,000	Ga. Power Co. 1st ref. 5s.....			1967	M-S	320,112.50
300,000	Gatineau Power, 1st 5s.....			1956	J-D	298,750.
75,000	Great Western Power Co. 1st Mtg. sink. 5s.....			1946	J-J	77,125.
100,000	Gulf States Util. Co. 1st 5s.....			1956	M-S	94,937.50
100,000	" " " " 4½s.....			1961	J-D	94,250.
100,000	Houston Ltg. & Power Co. 1st lien & ref. 4½s.....			1981	D-J	98,375.
100,000	Idaho P. Co. 5s.....			1947	J-J	100,750.
100,000	Illinois P. & L., 1st & ref. 5s.....			1956	J-D	196,750.
200,000	Indianapolis P. & L. 1st 5s.....			1957	J-J	198,806.25
200,000	Ind. & Mich. Elec. Corp., 1st ref. 5s.....			1955	M-S	202,182.50
300,000	Inter. Tel. & Tel. deb. 4½s.....			1952	J-J	288,250.
280,000	Int. Rap. Trans. ref. 5s.....		*	1966	J-J	276,701.
43,000	Kan. City P. & L. 1st 4½s.....			1961	F-A	39,085.
35,000	Louisville G. & Elec. 1st & ref. 5s.....			1952	M-N	33,843.75
300,000	Memphis P. & L. 1st & ref. 4½s.....			1978	A-O	279,250.
300,000	Milwaukee E. R. & L. ref. & 1st 5s.....			1961	J-D	302,337.50
100,000	Minn. P. & L. 1st & ref. 4½s.....			1978	M-N	92,156.25
150,000	Montreal Light, H. & P., sinking fund 5s.....			1970	M-S	135,950.
109,500	Narragansett E. Co. 1st 5s.....			1957	J-J	109,288.47
50,000	Newark Cons. Gas Co., Cons. Mtg., 5s.....			1948	J-D	50,750.
52,000	N. Eng. Tel. & Tel. 5s.....		*	1952	J-D	51,748.
100,000	New Orleans Pub. S. 5s.....			1955	J-D	99,200.
50,000	N. Y. Edison 1st ref. 6½s.....		*	1941	A-O	55,573.75
42,000	N. Y. Gas, E. L. H. P. pur. mon. 4s.....		*	1949	F-A	34,620.50
60,000	N. Y. & Westchester Ltg. 5s.....			1954	J-J	62,240.
300,000	New York P. & L., 1st 4½s.....			1967	A-O	286,125.
60,000	Niagara Falls P. 1st & con. 5s.....			1959	J-J	61,800.
150,000	Northern Ind. Pub. S., 1st ref. 5s.....			1966	M-N	152,887.50
150,000	Northern Ohio Traction & L. gen. & ref. 6s.....			1947	M-S	154,175.
100,000	Northern States P. 1st ref. 5s.....			1941	A-O	99,709.50
200,000	No. States Power Co., ref. 4½s.....			1961	A-O	195,000.
175,000	Ohio Power Co., 1st and ref. 4½s.....			1956	J-D	163,439.06
200,000	Okla. G. & E. 1st 5s.....			1950	M-S	200,000.
125,000	Pac. G. & E. Co. gen. & ref. 5s (\$100,000 registered).....		*	1942	J-J	123,240.96
25,000	Pac. Tel. & Tel. 5s.....			1952	M-N	26,187.50
300,000	Penn. Power & L. Co., 1st mtg. 4½s.....			1981	A-O	289,562.50
115,000	Penn. W. & P. 1st ref. 4½s.....			1968	M-S	111,736.74
350,000	Phila. E. Co. 1st & ref. 4½s.....			1967	M-N	351,733.01
136,000	Pub. Serv. Co., of Indiana, 1st & ref. 6s.....			1952	F-A	112,540.
160,000	Pub. Serv. of No. Ill., 1st ref. 5s.....			1956	A-O	157,550.
20,000	Pub. Serv. of No. Ill., 1st Lien & Ref. 6½s.....			1937	J-J	18,100.
152,000	" " " " E. & G. 1st & ref. 4½s.....			1970	F-A	147,520.92
48,000	Pub. Serv. E. & G. 1st. & ref. 4½s.....			1967	J-D	48,830.
60,000	Puget Sound Power & L. 1st & ref. 4½s.....			1950	J-D	56,550.
40,000	" " " " " " " " 5½s.....			1949	J-D	26,625.
82,000	Rochester Rwy. & L. 5s.....			1954	J-J	80,540.
10,991,500	Carried forward.....					10,751,653.40

CARNEGIE INSTITUTION OF WASHINGTON

Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Public Utility and Municipal—Continued</i>					
\$10,991,500	Brought forward.....					\$10,751,653.40
75,000	Rochester Gas & Elec. Corp. gen. 5s.....			1962	M-S	69,475.
50,000	Safe Harbor Water P. Corp. 1st 4½s.....			1979	J-D	48,861.07
50,000	San Francisco, Hetch Hetchy Bond, 5¾s.....			1960	J-D	53,523.34
200,000	San Joaquin L. & P. Corp., ref. 5s.....			1957	J-J	201,968.75
300,000	Shawinigan W. & P. 1st & coll. 4½s.....			1967	A-O	286,212.50
50,000	So. Bell Tel. & Tel. 1st sink. 5s.....			1941	J-J	47,687.50
250,000	So. Calif. Edison Co., ref. 5s.....			1952	M-S	256,214.58
50,000	So. Calif. Tel. Co. 1st ref. sink. 5s.....			1947	M-N	46,000.
200,000	So. Pub. Util. Co. 5s.....			1943	J-J	200,000.
25,000	Syracuse Lighting Co. 1st and ref. 5½s.....			1954	F-A	25,937.50
125,000	Tenn. E. & P. 1st and ref. 5s.....			1956	J-D	127,037.50
300,000	Texas Electric Service, 5s.....			1960	J-J	292,700.
100,000	Toledo Edison 1st. Mtg. 5s.....			1962	M-N	95,250.
223,000	Union Elec. Light & Power Co. 5s.....			1967	F-A	225,455.
220,000	Utah L. & T. Co., ref. 5s.....			1944	A-O	215,193.
300,000	Va. E. & P. Co. 1st and ref. 5s.....			1955	A-O	301,606.25
235,000	Washington Water Power Co., 1st and gen. mtg. 5s.....			1960	J-J	237,496.87
13,744,500	Public Utility Sub-Total.....					13,482,272.26
	<i>Mortgages</i>					
25,000	Empire Title and Guarantee Co., Guaranteed 1st Mortgage, Ctf. No. 278 5½%.....	*		1934	M-S	25,000.
100,000	Lawyers Mtg. Co. Guaranteed 1st Mtg. Ctfs., Series 18397 5½%.....	*		1935	J-J	100,000.
80,000	Lawyers Title and Guaranty Co., 5½% Mortgage.....	*		1935	A-O	80,000.
100,000	1st Mortgage 1184 Cromwell Ave., N. Y. 5½%.....	*		1932	M-S	99,500.
100,000	1st Mtg. N. W. cor. Westbury Ct & Flatbush Ave., Brooklyn 5½%.....	*		1933	M-N	100,000.
100,000	Mortgage-Bond Co. of N. Y. 5s (Certificate of Deposit).....	*		1938	J-D	96,000.
90,000	N. Y. Title and Mtg. Co. Guaranteed 1st Mtg. Ctf., 5½%.....	*		1938	A-O	90,000.
100,000	N. Y. Title & Mtg. Co., 1st 5½s.....	*		1933	J-J	100,000.
100,000	Title Guarantee and Trust Co., 1st Mfg. Ctf. 130057 5s.....	*		1937	J-D	100,000.
795,000						790,500.
	<i>Industrial</i>					
197,000	Aluminum Co. of A. 1st sink. deb. 5s.....			1952	M-S	198,057.49
50,000	American Radiator Co., deb. 4½s.....			1947	M-N	49,125.
40,000	Gulf Oil Corp., deb. 5s.....			1937	J-D	38,798.75
150,000	Gulf Oil Corp., sink. deb. 5s.....			1947	F-A	151,852.50
110,000	Lacka. Steel conv. 1st 5s.....			1950	M-S	112,925.
110,000	Liggett & Myers 7s.....			1944	A-O	130,058.77
110,000	Lorillard Co. 7s.....			1944	A-O	128,614.75
94,000	Midvale S. & O. conv. 5s.....			1936	M-S	94,205.
8,000	Park & T. Co. sink. deb. 6s.....			1936	J-D	6,400.
200,000	Rwy. Express Agency, 5s.....				M-S	200,000.
327,000	Stand. Oil N. Y. deb. 4½s.....					314,926.98
2,000,000	Tenn. C. I. & R. Co. 5s.....			1951	J-J	2,000,000.
150,000	Tex. Corp., Sinking deb. 5s.....			1944	A-O	141,957.30
129,000	Youngstown S. & Tube 1st sink. 5s.....			1978	J-J	125,208.32
58,000	" " " " " " " ".....			1970	A-O	39,262.50
3,733,000	Industrial Sub-Total.....					3,731,392.36
	<i>Stocks</i>					
50,000	A. T. & S. Fe pref. stock.....	*			F-A	52,125.
200,000	Cons. Gas. Co. Cum. pref. stock.....	*			FMAN	198,725.
100,000	Du Pont de Nemours, deb. Stock.....	*			JAJO	116,125.
50,000	J. I. Case Thresh. M. Co. pref. stock.....	*			JAJO	62,225.
40,000	Union Pac. R. R., pref. stock.....	*			A-O	33,415.
500,000	U. S. Steel Corp., pref. stock.....	*			MJSD	715,173.50
940,000	Stock Sub-Total.....					1,177,788.50

REPORT OF AUDITORS

Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Foreign</i>					
\$180,500	German External Loan of 1924 7s.			1949	A-O	\$192,840.72
100,000	Govt. of Argentina 6s.			1960	M-S	97,625.
115,000	Imp. Japanese Govt. 5½s.			1965	M-N	103,212.50
300,000	Kingdom of Denmark, ext. 4½s.			1962	A-O	274,375.
25,000	City of Montreal 5s.			1956	M-N	24,062.50
75,000	City of Montreal sink. 5s.			1954	M-N	72,375.
100,000	City of Montreal 4½s.			1946	F-A	94,368.90
200,000	New South Wales, ext. 5s.			1958	A-O	189,562.50
100,000	Province of Alberta deb. 4½s.			1958	J-J	93,750.
100,000	Province of Alberta 5s.		*	1950	A-O	101,125.
100,000	Province of British Col., 4½s.			1951	J-J	98,875.
100,000	Province of British Col. deb. 5s.			1939	J-J	100,412.67
100,000	Province of British Col. deb. 5s.			1954	A-O	99,000.
200,000	Province of Manitoba deb. 4½s.			1958	A-O	190,515.70
100,000	Province of Nova Scotia 4½s.			1952	M-S	100,312.50
100,000	Province of Ontario 4s.			1964	M-N	87,150.10
60,000	Province of Ontario 5½s (\$25,000 registered).		*	1937	J-J	61,291.10
100,000	Province of Ontario 5s.			1959	M-N	99,789.63
40,000	Province of Ontario 6s.			1943	M-S	43,137.50
30,000	Prov. of Saskatchewan deb. 5s.			1943	J-D	30,627.44
75,000	Toronto Harbour Comm. 4½s.			1953	M-S	72,062.50
100,000	City of Toronto con. deb. 5s.		*	1949	J-D	96,152.42
90,000	City of Toronto, 5s.			1952	J-D	89,333.53
50,000	City of Winnipeg inter. deb. 5s.			1943	J-D	48,250.
50,000	City of Winnipeg deb. 6s.			1946	A-O	53,500.
100,000	City of Winnipeg deb. 4½s.			1946	J-D	95,375.
2,690,500	Foreign Sub-Total.					2,609,082.21
34,973,000	Aggregate—Funds Invested.					34,437,983.18

REPORT OF AUDITORS

Real Estate and Equipment, Original Cost

<i>Administration (October 31, 1933)</i>			
<i>Washington, D. C.</i>			
Building, site, and equipment.....			\$403,546.54
<i>Division of Plant Biology (September 30, 1933)</i>			
<i>Palo Alto, California (Headquarters)</i>			
Buildings and ground.....	\$157,903.63		
Laboratory.....	46,895.04		
Library.....	23,032.71		
Operating appliances.....	23,617.92	251,449.30	
<i>Department of Embryology (September 30, 1933)</i>			
<i>Wolfe and Madison Sts., Baltimore, Md.</i>			
Library.....	2,896.68		
Laboratory.....	12,393.14		
Administration.....	6,661.08	21,950.90	
<i>Department of Genetics (September 30, 1933)</i>			
<i>Cold Spring Harbor, Long Island, N. Y.</i>			
Buildings, grounds, field.....	287,554.10		
Operating.....	26,053.07		
Laboratory apparatus.....	21,084.52		
Library.....	38,863.27		
Archives.....	45,488.90	*419,043.86	
<i>Geophysical Laboratory (September 30, 1933)</i>			
<i>Upton St., Washington, D. C.</i>			
Building, library, operating appliances.....	214,505.53		
Laboratory apparatus.....	140,261.67		
Shop equipment.....	15,314.63	370,081.83	
<i>Division of Historical Research (September 30, 1933)</i>			
<i>Tower Building, Washington, D. C.</i>			
Operating.....	12,505.58		
Library.....	7,140.96	19,646.54	
<i>Tortugas Laboratory (September 30, 1933)</i>			
<i>Tortugas, Florida</i>			
Vessels.....	30,930.43		
Buildings, docks, furniture, and library.....	12,130.86		
Apparatus and instruments.....	9,322.55	52,383.84	
<i>Department of Meridian Astrometry (September 30, 1933)</i>			
<i>Dudley Observatory, Albany, N. Y.</i>			
Apparatus and instruments.....	4,846.84		
Operating.....	5,266.68	10,113.52	
<i>Nutrition Laboratory (September 30, 1933)</i>			
<i>Vila St., Boston, Massachusetts</i>			
Building, office, shop, and library.....	131,696.71		
Laboratory apparatus.....	36,054.11	167,750.82	
<i>Mount Wilson Observatory (August 31, 1933)</i>			
<i>Pasadena, California</i>			
Buildings, grounds, road, and telephone line.....	202,474.64		
Shop equipment.....	45,855.44		
Instruments.....	665,262.58		
Furniture and operating appliances.....	196,216.92		
Hooker 100-inch reflector.....	606,181.53	1,715,991.11	
<i>Department of Terrestrial Magnetism (September 30, 1933)</i>			
<i>5241 Broad Branch Road, Washington, D. C.</i>			
Building, site, and office.....	223,724.21		
Survey equipment.....	95,246.51		
Instruments, laboratory, and shop equipment.....	165,889.62	484,860.34	
		3,916,818.60	

* Including Harriman Fund property in the amount \$183,671.75 shown as a separate item on the Balance Sheet.

REPORTS ON INVESTIGATIONS

DEPARTMENT OF EMBRYOLOGY¹

GEORGE L. STREETER, DIRECTOR

It should perhaps be explained that the following report is limited to researches that have been completed and published prior to June thirtieth of the current year. Thus it deals entirely with past and already cold events. The thought arises whether it would not be better to describe work now in progress, the difficulties that are being met and our tentative plans for the future. Although these circumstances are of intense concern to the investigators themselves and are forceful stimuli to endeavor, they have been scrupulously eliminated. This is done under the convictions that only in a limited degree can the affairs of research be predicted, that opportunism often plays a larger part in discovery than long-distance planning, and that the investigator is on the fringe of the unknown where in his uncertain advances he must be sensitive to advantageous alterations in course. It is not necessary to go all the way with those who say that no man goes so far as he who does not know where he is going, but the limitations of rigidly planned and far-flung research must, however, be recognized. For that reason the writer whose function it is to record the research progress of the group of investigators associated with the Department of Embryology assumes that ambitions for the future and partially completed work are more in the nature of personal than of general scientific interest and hence do not belong in the limited space available in the pages of this report.

Of the work to be reported, there are various items and the order in which they will be treated is merely one of convenience. As will be seen, they are all in some way related. There is first described how it has been possible, by comparison with monkey embryos of known age, to arrive at more precise age-estimates of young human embryos. Through studies made on embryos of the fly, processes in the formation of tissues have been recognized which are of importance to embryology in general. Factors in the determination of body-form have been demonstrated by means of comparative studies on primate fetuses. Maldevelopment has been investigated by experimental procedure and by genetic analysis. Experimental evidence of autonomous movements of chromosomes has been obtained which is in harmony with phenomena that had previously been revealed through means of motion pictures. Using the technique of tissue culture, it has been possible to demonstrate class distinction among certain white blood cells. Additional information has been obtained on the nature of the supporting cells of the central nervous system. Malignant tumor cells have been studied with reference to their specific structure and their abnormal behavior in cell division. Some of their characteristics have been artificially induced in normal cells by means of radium irradiation and chemical agents. New tissue-culture techniques which have been developed in the course of these studies are described.

In the field of physiology of reproduction, experimental evidence has been obtained on some of the factors involved in the transport of ova and sperm, on viability of the latter and on the cause of menstruation. A behavioral

¹ Address: Wolfe and Madison Streets, Baltimore, Maryland.

study has been made of the new-born monkey and the interreactions between it and its mother. Further study has been made of hormones and their interrelation which play so large a part in the activity of uterine muscle. An application of this information has been made to certain abnormal states of the uterus in woman. It has been shown that pituitary hormones are prevented from passing from the fetus to the mother by the placental barrier, at least in a biologically effective state.

Finally there are included studies made on the adult organism. Observations have been made on the nature of variations in arterial patterns. Species variations and generic determination in higher forms and the homologies of fins in fishes have been analyzed. The central nervous system is shown to be essentially non-metameric. Studies have been made on nerve-muscle relationship. Observations have been made on the innervation of the ureter. Regeneration in the sympathetic nervous system following pre- and post-ganglionic injury has been studied, resulting in detailed information as to the repair and fundamental data on some of the most primitive reflexes. The grasping reflex has been studied in the new-born monkey. Important advances have been made in our knowledge of the cerebrospinal fluid, particularly as to the rate of its formation, the manner in which it functions and the mechanical features of the membranous space within which it is inclosed. Studies of the various pressure alterations involved in postural changes indicate that an important role is played by the cerebrospinal fluid system in the maintenance and adjustment of these pressures, something more vital than the sluggish drainage mechanism and the protective shock cushion which have been accredited to it.

NORMAL AND ABNORMAL EMBRYOGENESIS

In lower forms it has been possible ever since the embryos were recognized to speak of their age with some precision. Much has been known regarding their rate of development and the range of variation in the rate, along with the factors influencing it. Copulation age of some of the embryonic stages has been recorded in several mammals, and in the mouse the embryos have been accurately dated with respect to ovulation. In primates, however, knowledge of these matters has been extremely scant. Ovulation age, which is the crucial one from the standpoint of embryology, was unknown for any specimen. As for human embryos, resort has been had to their correlation with the last respective menstrual period, although their time-relation to it was merely speculative and the data were derived from the fallible records of patients. Circumstantial evidence of various forms in addition to the menstrual data has, however, led to a general consensus regarding the probable age of the principal stages of development. During the past two years we have been able to obtain from Dr. Hartman's colony primate embryos of known ovulation age, so that one can now speak of their real age and rate of development with the same precision possible in lower forms. This marks a new era in primate embryology.

Now that macaque embryos of known age have become available, it is possible to compare human embryos with them and arrive at age-estimates of greater value than those heretofore prevailing. It is true that the two

genera, man and monkey, differ in details of form and in rate of differentiation and growth. But these differences when plotted on a chart do not become appreciable until the end of the second month, whence their curves of growth diverge with accelerating rapidity. We may, therefore, at least for the first month or six weeks, transfer the ages known for the *Macacus rhesus* to human embryos of corresponding development. This has recently been done by the author and the ovulation age of some of the early stages of development has in this way been arrived at. The Peters' embryo is rated at 13 days. At 20 days, Hensen's node, a notochordal process and primitive groove, are present. The first somites make their appearance on the 22d day. Segmentation of somites proceeds rapidly as 1, 5 and 8 somites are found on the same day. A 6.5-mm. embryo with triangular fin-like arm buds and beginning leg buds was obtained on the 27th day. Older specimens were obtained as follows: 29 days, 7.6 mm.; 32 days, 10.5 mm.; 35 days, 12 mm., with definite finger rays; and 38 days, 13.0 mm. A specimen of 75 days showed a sitting height of 110 mm., but by that time it had already taken on its anatomical specializations and could no longer be matched with human specimens.

HUMAN EMBRYOLOGY

In the new reference hand-book on obstetrics and gynecology edited by Dr. A. H. Curtis, the chapters on maturation and fertilization of the ovum and the early development of the embryo were written jointly by Dr. C. G. Hartman and Dr. B. M. Patten. Throughout their pages there is included much new material originating from this laboratory. These chapters will acquaint the medical reader with a new standard of embryological presentation in which old diagrams have been in large part replaced with photographs, drawings and descriptions of actual specimens, thus enabling him to base his concepts on approximately first-hand knowledge. Granting this as their main purpose, these chapters will also serve as statements which will be of importance to specialists in embryology, notably teachers. Furthermore, mention should be made of the chapter on the embryology of the female generative tract by Dr. A. K. Koff, giving a summary of his own recent researches. The final publication of his studies is now in press for the Contributions to Embryology and will be referred to in next year's report.

EMBRYOLOGY OF THE FUNGUS FLY

Although in making a detailed study of the embryology of the fungus fly, *Sciara*, it was the purpose of Dr. A. M. DuBois to serve the needs of Dr. Metz and to provide a developmental basis for the analysis of his *Sciara* observations, her studies at the same time have uncovered phenomena which are of great importance to embryology in general. A point of particular interest is the chromosome elimination occurring during cleavage, which was referred to in my report of last year. Dr. DuBois found that during the first five cleavages, each nucleus has a full number of ten or eleven chromosomes. It is at this time that the germ cells take up their position at the posterior end of the egg and thus separate themselves from the general somatic nuclei. The latter, already having reached the surface of the egg, exhibit during their next four cleavages the significant phenomenon of elimination of

chromosome material. As the chromosomes draw apart at the anaphase stage, those that are to be eliminated stay midway on the division spindle with the result that as the two daughter nuclei separate there is left behind a chromatin mass. Small chromatin masses of this kind can be seen in the yolk for some time—and even after the embryo is segmented—though they eventually disappear. The peculiar behavior of the chromosomes in this fly is of great interest because of its bearing on the general theory of the heredity of sex. One wonders if any “genes” are included in this discard of chromatin material.

An interesting feature of the blastodermic stage is the proliferation and migration of the germ cells. In the embryonic development of insects it would appear that the process of growth (multiplication of cells) and the process of differentiation (adaptation or migration) do not occur simultaneously, the whole embryology being a succession of periods of differentiation interpolated between periods of proliferation. At any rate the germ cells remain at the posterior end of the egg until there are from 22 to 28. They then begin to migrate and there is no further division until they have reached their definitive position.

During the migration of the germ cells, the somatic part of the embryo begins its transformation into three embryonic layers. These were traced by Dr. DuBois and the morphogenesis of the chief body parts was deciphered. The mammalian embryologist will be impressed by the resemblances between some of the developmental processes of the insect and those of the remote mammal. To mention one, the oral end of the embryo is more precocious than the more caudally lying parts, that is, the development extends in the cranio-caudal direction.

Identification was made by Dr. DuBois of the primordia of the antennæ, eyes, legs, wings, halteres and genitalia. The sex difference of the latter was determined and also there is added a morphological study of the whole reproductive tract of the mature flies. Gynandromorphs that occasionally occur were studied, and it was found that they show various mosaics of male and female parts. Furthermore it was found that both gonads are always of the same sex, either two testicles or two ovaries, proving that the germ line is not affected by the chromosome disturbances producing the monstrous development. This material would seem to offer great opportunities for the experimental embryologist.

ORANG-UTAN FETUSES

Adding to his previous observations on orang-utan fetuses, Dr. A. H. Schultz has had the opportunity of studying a particularly valuable prematurely born female specimen obtained from the Zoological Society of Philadelphia. This completes a group of six specimens of this species, including older fetuses, a new-born and a young infant, which have been studied by him and whose body development and proportions he has been able to compare with the adult condition. In this interesting animal it is very obvious that the fetus is not merely a small edition of the adult. Dr. Schultz finds that the proportion of the body parts are notably different in many respects. Compared with the adult the fetus has a stouter trunk, a relatively narrower

chest, proportionately longer upper limbs, relatively shorter forearms, relatively longer thumbs, broader hands, a proportionately much larger brain case and a corresponding smaller facial region with relatively large ears. It will be noted that in these anatomical characteristics, the adult shows marked and specific deviations.

An item of especial interest is the development of the cheek pads, particularly in male fetuses. Though having no known function, these curious structures make their appearance in fairly early fetal life in males. Traces of them may also be present in the female. At least in this new female specimen two streams of hair directed against each other marked out a crest in front of the ear corresponding to where cheek pads would develop were it a male. Other items to which especial attention was directed include the coccygeal pigmented spot, the Schultz sternal pit, retardation of the nails, variations in skin color, and the pigmentation, distribution and direction of the hair.

ORTHODONTIC STUDIES IN MONKEYS

Owing to the fact that we have in our rhesus colony many animals of known age, it has been possible, by placing these animals at his disposal, to assist Dr. J. A. Marshall of the University of California in his studies on the development, absorption and movement of teeth. As a guest of Dr. Hartman he made radiographs of selected animals, thus completing his series and dating the principal steps of the process of calcification. It has been of value to compare his records of the living with Dr. Schultz's observations based on cleaned and dry material.

DEFECTS IN DEVELOPMENT OF PIGMENT

It has been found by Mrs. M. R. Lewis that when frog eggs are grown in water containing a small amount of the dye phenol indophenol, they exhibit a defect in the development of the pigment-layer of the optic cup and a marked pallor of the skin. The injury brought about by the dye appears to be a specific one limited to the pigmentation tissues, the growth of the tadpoles being otherwise normal. Tadpoles were grown in solutions containing various other dyes, but specific abnormalities were only obtained with the indophenol dyes. Of the latter, several forms were used and they all resulted in pigmentation abnormalities.

When the eggs are placed in the dye solution during the early stages of segmentation, defective pigmentation results in both eye and skin, involving contraction and loss of the pigmented chromatophores together with a loss of melanin from the ectoderm cells of the skin and an absence of the pigmented layer of the optic cup. The optic cups in these cases tend to be collapsed and evidently suffer some damage in addition to the loss of the pigmented layer. The original pigmentation of the egg begins to disappear at the end of the first week. At the end of two weeks there is marked loss of pigment from the optic cup and by the end of three weeks the loss is practically complete both in eyes and skin. If, however, the eggs are not exposed to the dye until they reach the tadpole stage, the loss of pigment is limited to the skin, whereas the eyes are normal.

Further, it was found that tadpoles albinized by the dye, when injected with or placed in water containing pituitary extract, do not acquire pigment. This indicates that the defect is a direct injury and is not secondary to a pituitary deficiency. It can not be remedied by substitution therapy as in those pigmentation disturbances which follow the removal of the pituitary gland.

INHERITANCE OF EYE DEFECTS

In a previous report, Year Book No. 23, there was occasion to refer to a study of familial retino-cerebral degeneration in which it was concluded that it involved a congenital lowered vitality or vulnerability of the part concerned. The exigencies of the normal activities of the organ resulted in its premature senescence and the breaking down of its tissues. During the past year another familial eye defect in man has been studied by Dr. C. F. DeGaris with Dr. E. T. Hornback. In a mating of first cousins of whom the female had cataract there issued in four generations a progeny of 138 individuals of whom 23.8 per cent had cataract. If the members whose eye condition is unknown are omitted, there are 29 known to be unaffected and 30 known affected, that is, about 50 per cent.

On studying the pedigree by generations, the investigators have concluded that according to genetic terminology cataract is inherited as an autosomal, *i.e.* mendelian, dominant. It is atypical, however, in being transmitted in some instances without producing in the bearer its characteristic defect. Presumably certain conditions are necessary for the realization of the defect, conditions, however, which would not cause it in the absence of a genetic predisposition. Those in which the cataract is transmitted in an atypical manner are regarded as cases where such conditions are not present.

CYTOLOGICAL STUDIES

MONOCENTRIC MITOSIS

New evidence has been obtained by Dr. C. W. Metz on the mechanism of chromosome movement. A question has existed as to whether the chromosomes are entirely passive and depend for their movement on attraction and repulsion forces emanating from outside, or whether their movement is due to their own autonomous activity. In studying monocentric mitosis as it occurs in the fungus fly, *Sciara*, Dr. Metz has made observations indicating that an autonomous activity of chromosomes exists. Whether or not it is the sole force is another matter.

In the first spermatocyte division, the six elect chromosomes collect at the pole, whereas the four undesired chromosomes retreat to the opposite side of the cell, are cast off as a bud and degenerate. Dr. Metz has found that by chilling the material at the proper time, although without the perfect control that might be desired, the retreat of the undesired chromosomes can be arrested and these are therewith retained within the cell until the second spermatocyte division. Under these circumstances while the chromosomes of the regular nucleus are going through their usual performance of interkinesis, prophase and metaphase, the artificially retained chromosomes go through a similar series of stages including splitting. Having no aster or

spindle, however, the daughter halves of the retained chromosomes can not separate but remain together, while the regular nucleus is completing the anaphase of the second division.

From these observations it is clear that the retreating chromosomes in monocentric divisions are alive and capable of taking an autonomic part in mitotic movements. The difference between their activity and those that go to the pole is evidently due to the sex of the parent from which the chromosomes were derived.

Supporting this experimental evidence, Dr. Metz finds various cytological reasons for concluding that the chromosomes are, at least in part, autonomic in their movements. Among these are to be mentioned the independent movements relative to each other of the four retreating chromosomes in monocentric division; in the extrusion bud, the chromosomes are at the apex of the moving mass, which would not be so were they not responsible for the movement; and when the bud is cast off the chromosomes are still undergoing visible changes, resembling those of the retained chromosomes, proving that they are not discarded as dead inert material. These observations have a direct bearing on the inter-relation between cytoplasm and chromosome, on sex determination, and the influence of sex on chromosomal behavior. This evidence is in harmony with the observations on chromosome movements made by Dr. and Mrs. Lewis in sarcoma cells by means of motion pictures.

WHITE BLOOD CELLS AND MACROPHAGES.

No rigid classification of blood cells has been yet arrived at comparable to the genealogical tree of the comparative anatomists. The hematologist has not yet decided upon phylum, class, order, genus and species, though the morphological variety of blood cells seems great enough to warrant such a phylogenetic classification, and it might be done with better proof than the comparative anatomist is satisfied with. If we are to understand the finer anatomy and function of the white blood cells, the genetic relationship of the three related groups, the granulocytes, lymphocytes and monocytes, is of great importance. The occurrence of "transitional" forms, having characteristics common to neutrophiles (belonging to the granulocytes) and to monocytes, suggested the possibility that one might change into the other. A method of testing this was devised by Dr. W. H. Lewis and Dr. M. I. Rubin. They made serum cultures of particles of the buffy coat of human blood and studied the white cells which migrated out. They found that the neutrophiles and monocytes can always be distinguished one from the other. These types both undergo degenerative changes which increase their resemblance, but they could usually be identified and thus there was obtained no evidence of actual transition between the two forms. At first it appeared that there was such a transition. It happens that the neutrophiles migrate out earlier, at which time the culture is made up mostly of this type. Later the culture is made up largely of monocytes and these would appear to have been a change of neutrophiles into monocytes. The change in the count, however, proved to be due to sedimentation of the neutrophiles to the bottom leaving only the monocytes in the surface field, supplemented by belated

migrating monocytes. When the transplant is removed early, when only neutrophils have migrated out, reculture of the latter fails to produce monocytes.

It is to be remembered that white blood cells do not always stay in the blood stream. They live an amphibious existence, the varieties differing as to the duration of their extravascular sojourn, some being in permanent exile and some never having been in the blood stream at all. The macrophage is of the latter sort. In my report of last year an account is given of the observations of Dr. Mihálik who studied cultures of the chick embryo brain and identified the cells wandering out from the explant as macrophages. Since then his final paper has been published, in which he includes a microscopical analysis of his preparations. There is left no doubt as to the identity of the cells that wander from the central nervous system and that they are present from the 3-day old embryo to the adult animal. These observations throw light on the nature of microglia cells with which he concludes they are identical. It proves that these cells are present in the embryo much earlier than was supposed. Their exact histogenesis must be arrived at by some other approach.

THE MALIGNANT CELLS OF RAT SARCOMAS

When grown in tissue culture, apparently all malignant cells differ morphologically from normal fibroblasts. It may be but little, such as a larger nucleus and more refractive cytoplasm or it may be a marked difference involving several characteristics. It becomes of importance to learn whether the malignancy is due to this permanent visible alteration of the cell or whether it is due to an invisible factor which in turn is the cause of the alteration.

With the purpose of determining in what manner malignant cells differ from normal ones, thirteen different rat sarcomas have been cultured by Mrs. M. R. Lewis and Dr. W. H. Lewis. One of them exhibiting extreme differences, Walker sarcoma 338, was studied in detail. Bits of tumor were cultured in chicken plasma, with and without vital dyes, and many motion pictures were made, particularly to show dividing cells. They found that as compared with normal fibroblasts, the malignant cells of this strain are larger, the cytoplasm denser and more granular and the mitochondria more finely divided. There are certain nuclear differences and there is a pronounced centrosphere. The most striking difference, however, is the frequent occurrence of atypical, abortive and abnormal mitosis. There is also a great variation in chromosome number, with aberrant chromosomes and chromosome vesicles. These investigators do not regard the malignancy as due to alterations in the chromosomal number, for they find that cells with the normal number may be just as malignant as those with abnormal numbers. The possibility is suggested that the centrosomal mechanism may play a more determinative role in mitosis than the chromosomes themselves, and that alterations in it may be the key to the malignancy of the cells and the explanation of the abnormal chromosome behavior.

Another rat sarcoma, Walker sarcoma 319, has been studied by Dr. W. Schopper, of the University of Giessen, who as Rockefeller Fellow was a

recent guest of the laboratory. Using various culture mediums, he made observations on the nature of the growths and of morphological and physiological characteristics of the individual sarcoma cells. In this case the malignant cells showed but slight morphological differences from the normal fibroblast. Instead, the difference rested in their more vigorous and rapid growth. This activity was found both in the outgrowth and in the tumor fragment, throughout which was seen a great abundance of mitotic figures. As in the tumor studied by Dr. and Mrs. Lewis, there occurred many abnormal division figures, aberrant chromosomes, tripolar figures and unequal division of chromatin. As a rule the division-figures were bipolar with a normal chromosome count, but there were also instances of hyperdiploid and subdiploid counts. The macrophages and detached endothelial cells contained in the cultures could be clearly distinguished from the malignant cells and presented no abnormality. By introducing in his cultures india ink and red blood-cells of the chicken, Dr. Schopper was able to demonstrate that sarcoma cells around the spreading margin of the explant are actively phagocytic.

Another point of difference between malignant sarcoma cells and normal fibroblasts resides in the nucleus. Dr. W. H. Lewis has found that in living cells, instead of the clear homogeneous nuclei of the fibroblast, the malignant cells have a heavier nuclear membrane and are granular, the latter condition being more marked in some sarcomas than in others. By adding certain acids to cultures of normal fibroblasts he was able to induce the same characteristics in them which could be reversed on returning them to the normal medium. Furthermore, malignant cells subjected to ammonia vapor lose their granular condition, the nucleoplasm becomes homogeneous and the heavy nuclear membrane becomes thin and barely perceptible. On placing them in a slightly acid medium the granular condition and the heavy nuclear membrane returns. In this way Dr. Lewis has demonstrated that the characteristic appearance of the nuclei in these living malignant cells is concerned with a state of reversible coagulation.

Mrs. M. R. Lewis had already shown that in malignant cells during mitosis, the chromosomes become more widely split than those of normal cells. During the past year she has found that this characteristic can be produced in normal cells without arresting their division and further growth. It was only necessary to dilute the culture medium with distilled water during mitosis. When this is done, the split extends along the whole length of each chromosome, giving the latter the same appearance of parallel bodies that is characteristic of mouse malignant cells. These experimental cytological studies in addition to explaining appearances found in cancer cells are extending our acquaintance with the phenomenon of cell division.

CYSTICERCUS TUMORS

A variety of sarcoma can be produced experimentally in the liver of rats by means of tapeworm larvæ. When young rats are fed the eggs, a reaction occurs in the liver around the developing larvæ which results in the formation of cysts whose walls thicken and become transformed into mixed sar-

comas. Dr. W. Mendelsohn obtained some of this material from Dr. Bullock and Dr. Curtis of the Columbia University Institute for Cancer Research, and has succeeded in making tissue cultures of the walls of the cysts. In making a study of their cultural characteristics, he was able to identify the malignant cells which like those in the sarcomas studied by Mrs. M. R. Lewis and Dr. W. H. Lewis possess large, coarsely granular nuclei with distinct nuclear membranes. There were, however, not so many abnormal division figures, although tripolar mitosis was observed. It is of interest to note that the growth-promoting principle elaborated by the developing larvæ resulted in a greater activity of the non-malignant supporting elements in tissue cultures of infested material than is found in control cultures of corresponding normal tissues.

EFFECT OF VARIOUS AGENCIES ON CULTIVATED CELLS

The effect of radium irradiation on cultures of normal fibroblasts, tumor cells and macrophages has been studied by Dr. W. G. Whitman. Her observations include changes in morphology of the cells and more particularly the effect on rate of cell division and changes in the mitotic figures. In applying the emanations, filters were used which eliminated most of the beta rays, and thus the results were due almost entirely to the gamma rays. Irradiation has a definite deleterious effect on the chromosomes themselves and apparently injured the spindles. Cells in division at the onset of irradiation proceeded in a normal manner to complete mitosis. Shortly after irradiation, abnormal mitotic figures made their appearance, along with a variety of abnormalities of the chromosomes, some of which Dr. Whitman regarded as due to injury of the spindle substance. In comparing them with sarcoma cells it was found that macrophages were more affected by the treatment than were the tumor cells. Also the number of mitoses of normal macrophages was proportionately more reduced by irradiation than those of malignant cells.

In the report of this department for last year, mention was made of the experiments of Dr. M. Rosenfeld, who submitted cultures to the action of ether and other chemical agents. Since then he has completed a study of mitosis as modified by ammonia. Using chick fibroblasts, he found that exposure to ammonia, either in metaphase or anaphase, resulted in aggregation of the chromosomes in dividing cells, but on return to a normal medium the affected cells recovered normal appearing nuclei. The recovery resembled the normal process of reconstruction of young daughter nuclei from telophase chromosomes. Following such recovery, cell division was either completely suppressed or exhibited various abnormalities resembling those obtained by Dr. Whitman after radium emanation. Dr. Rosenfeld concluded that the initial chromosomal aggregation was due to the pH of the ammonia buffer alone, that is, it was something more than just the hydrogen ion concentration.

In connection with these studies, a belated reference should be made to the study by Dr. W. J. German on the effect of certain antiseptics on tissue cells growing in culture. Using five antiseptics which are in daily use in the

clinics, Dr. German studied their effect on living embryonic cells, correlating the results with a parallel series of determinations of the effect of the same dilutions on ordinary wound bacteria. The aim was to determine which of the five antiseptics had at the same time the highest bacteriostatic effect and the highest value for tissue viability. The maximum efficiency was found to be possessed by acriflavine and in dilutions of 1:800 to 1:1600. The others in their order were: picric acid, gentian violet and mercurochrome. Potassium mercuric iodide had the highest bacteriostatic effect, but unfortunately has a tissue viability of zero.

While visiting this laboratory, Dr. P. Mihálik completed a series of experiments using various media with the purpose of learning which of them was most favorable for the culture of nervous tissues and the outgrowth of nerve fibers. He found that nerve processes grow better in Locke-Lewis solution than in semisolid media, either plasma or embryonic extract. The nerve processes grow faster without the dextrose and peptone, but because of the emigration of the nerve cells the explants become disintegrated. The disintegration, however, is prevented by dextrose. In cultures during the growth process, the optimum pH was found to be 6.6 to 6.8, but it was found that the culture tends to bring the solution to this pH, whether originally it was higher or lower. Dr. Mihálik observed the formation of synapses in his nerve cultures.

TWO NEW CYTOLOGICAL METHODS

A simple and rapid method for determining the cytological characteristics of myxomatous tumors has been developed by Mrs. M. R. Lewis and Dr. R. E. Gardner. They have found that a thin slice of the tumor drawn over a cover-slip leaves a smear which while still fresh can be stained with a modified Wright's blood stain and which then yields a picture of the constituent cells and the color reaction of their nuclear elements and cytoplasmic granules with marked clearness and brilliance. With this method, they have studied infectious myxoma of the rabbit and have been able to demonstrate that the enlarged spindle and stellate connective tissue cells seen in sections represent the malignant cells. Other elements of the tumor such as monocytes, macrophages and epithelioid cells could in this manner be studied with great advantage. Though Wright's blood stain was the most satisfactory, other stains can be used where special needs demand them. It was found that Giemsa's stain was especially suited to bring out the myxomatous material in the stellate cells.

An improved technique for massive tissue culture has been developed by Dr. G. O. Gey. Where the maintenance of permanent strains of desired types of cells is called for, he has found that the tedious and laborious technique of the hanging drop method and its repeated transfers can be partially eliminated by utilization of the culture tube. A satisfactory device for slow rotation of a large number of such tubes has been developed and has now been in operation for over a year. A strain of sarcoma cells and a culture of human bronchiogenic carcinoma has been maintained under constant cultivation for several months. The success of the device has led to the installation of a duplicate apparatus which is being used by Dr. W. H. Lewis.

PHYSIOLOGY OF REPRODUCTION

TRANSPORT OF OVA AND SPERM

The normal period for the transport of rabbit ova through the tube into the uterus is something over 72 hours. It has been found by Dr. G. B. Wislocki and Dr. F. F. Snyder that if a supplementary set of eggs are caused to ovulate by means of injection of an extract of human urine of pregnancy, at about four days after a normal mating when the primary set of eggs have already reached the uterus, the experimentally induced second set passes through the tube in less than 60 hours, which is 12 hours quicker than is normal. From this it appears that the quiescent tube characteristic of pregnancy favors an accelerated passage of the ovum, whereas the rhythmic smooth-muscle activity which is maximum at the time of ovulation serves to delay its passage. Since the tubes differ histologically as well as in contractile activity during the ovulatory period as compared with the gravid period, it is possible that we have herein a clue to the nature of transport mechanism. At least the observation of these investigators demands an explanation. They refer to Corner's previous work in which it was shown that removal of the corpora lutea markedly retards the tubal transit. In contrast to this, in their experiments the number of corpora lutea is doubled and the transit is therewith speeded up. It would seem possible that the corpora lutea may play a decisive role in determining the physiological state of the tubes and the length of time required for transport of the ova.

Dr. Hartman has recently completed a survey of the present status of our knowledge of ovulation and the transport and viability of ova and sperm in the female genital tract. This appeared as one of the Chapters in *Sex and Internal Secretions*, edited by Professor Edgar Allen. Its content deals with an important phase of the physiology of reproduction and one that is still clouded in multiple uncertainties. The problems that still confront us are pointed out by Dr. Hartman and thus his review becomes a program of work.

In weighing the evidence regarding the mechanism of ovulation, he favors the growth-process theory, that is, the result of progressive cellular changes, rather than any of the theories involving intrafollicular pressure terminated by a cataclysmic rupture of the follicle wall. The time of ovulation in the cycle can be stated with considerable certainty, based on his own observations. Other phases discussed include alternation of function between ovaries, fertilization, viability of the egg and fate of the unfertilized egg. The transport of the ovum through the tube and the determination of the implantation site involve the consideration of many factors, which are fully presented by Dr. Hartman, but as often happens where there is much to be said, there is little to be concluded. His review of the viability and transport of the spermatozoa is also an important statement, based as it is on many details on his own observations on the opossum, rat and monkey, some of which are here published for the first time. This chapter is going to be frequently referred to by workers in this field.

SURVIVAL OF SPERMATOZOA

Among the bats, there are at least two species in which copulation, ovulation and fertilization are closely connected events. These two species may be regarded in this characteristic as closer to the main mammalian stem, conforming as they do to the mammalian type of reproduction. One of these, *Nyctinomus*, was studied several years ago by Dr. C. G. Hartman and Mr. W. K. Cuyler. Recently the evidence of prolonged viability of sperm in other species has been reviewed by Dr. Hartman and he accepts the evidence as valid that departing from the primitive habits of *Nyctinomus*, the typical female bat has developed secondarily the custom of storing in her genital tract a mass of spermatozoa, which survive hibernation of six to eight months and at the end of which time they are probably available for fertilization of eggs ovulated in the spring. The evidence only needs the critical experiment of shielding the female from repeated copulation during the winter. It remains necessary to prove that the sperms deposited in the fall are the ones that fertilize the ovum in the spring. However, there remains no doubt as to the long life of spermatozoa in the epididymis of the male bat, where they have been demonstrated to survive as long as seven months after cessation of spermatogenesis. Dr. Hartman points out two factors existing in the bat, and favoring survival of spermatozoa in the female genital tract, namely, the low body temperature and the immobilization of the sperm in a coagulum.

REPRODUCTIVE CYCLE IN ANIMALS

The appearance of a new Hand-book on Obstetrics and Gynecology edited by Dr. A. H. Curtis provided an opportunity for a reexamination of our information on some of the fundamental problems underlying the physiology of reproduction. Many of the studies and observations that have been made in recent years in this laboratory have found their way into this important Hand-book and a number of the reviews have been written by investigators associated with us. One of the chapters of wide interest comes from the pen of Dr. Hartman. In it he presents a brief résumé, but of wide scope, covering a comparative study of the reproductive cycle in animals. His familiarity with the subject-matter has enabled him to do the desirable thing of concentrating much pertinent information in the available number of pages.

THE GENITAL TRACT

Another publication of general interest has appeared during the past year and to which several members associated with our department have contributed. I refer to the *Growth and Development of the Child* published under the auspices of the White House Conference. The section on the genital tract was written by Dr. C. G. Hartman. Other chapters are mentioned elsewhere in this report.

MENSTRUATION

Dr. C. G. Hartman and Dr. E. Novak in their review for the Curtis Hand-book conclude that the facts are still too meager to assign to any

one factor the essential cause of menstruation. Since menstruation can occur without ovulation, they had supposed that follicular activity was ruled out, as has been mentioned in previous reports. It now seems probable that the numerous growing follicles of medium size have an influence on menstrual phenomena. It is the growth and decline of follicles and not of the corpus luteum that seems to be the essential factor. As long as folliculin is circulating in the blood, menstrual bleeding is inhibited. This would also explain intermenstrual bleeding, if one grants a failure of folliculin between ovulation and the establishment of a functional corpus luteum. A review of menstruation prepared by these two investigators is born under favorable auspices and is naturally replete with their own personal observations, Dr. Hartman in the field of comparative physiology, particularly the Carnegie Monkey Colony, and Dr. Novak in the hospital clinics and laboratories.

BEHAVIOR AND MATERNAL CARE OF THE NEW-BORN MONKEY

In a previous report, reference was made to the studies of Dr. O. L. Tinklepaugh and Dr. C. G. Hartman on the sequence of events in parturition of the monkey and the analysis of the various phenomena from the standpoint of behavior. During the past year a further study has appeared in its final form, covering the behavior of the new-born monkey and the reactions of the mother in the way of maternal care. Their data were obtained from observations upon eleven new-born animals, born in the Carnegie Colony within a period of six weeks. To this there have been added data obtained from subsequent pregnancies in our colony and one of another species of macaque born in the Yale colony. The behavior of the babies was studied during and immediately following birth. The behavioral development was then followed during the subsequent weeks along with establishment of relationships to the mother. Especial attention was given to the sensory-motor development of the young and note was taken of their emotional responses.

The full-term macaque baby opens and closes his eyes, cries, reaches out and grasps objects with his hands before he is completely delivered. At birth his flexor muscles are more precocious than his extensors, and their principal drive appears to be the seeking of bodily support. By the second day there is a tendency to climb upward. By the end of the first week all of the sensory mechanisms show evidence of functioning and the sensory-motor coordination develops much more rapidly than in the human infant. Play activities such as romping, jumping, attempts to leap upon and seize objects appeared during the second and third week, at which time, however, eye-hand coordination and distance perception were quite imperfect. In the mother-baby relationship much of the behavior is subject to mechanistic explanation. Equipped with his grasping tendencies and the associated ventroventral position, the nosing and mouthing activities of the infant result in the discovery and seizure of the nipple, unaided by the mother. It is in this way determined when and how he shall nurse. If the baby through immaturity lacks sufficient strength and coordination to accomplish these ends himself, the mother-instinct is inadequate for the predicament and he perishes.

ENDOCRINOLOGY

HORMONES AND UTERINE MOTILITY

The studies on uterine contractions which were under way last year in the hands of Dr. S. R. M. Reynolds have since been completed. Various aspects of this work were described in the last Year Book. Dr. Reynolds in the meantime has accepted a teaching position, with favorable opportunities for research, in the Department of Physiology, Western Reserve University. Fortunately before leaving, his main objectives in his visit to our department were attained and his interesting results have been published in their final form.

In his earlier experiments on the action of human urine of pregnancy in uterine motility, Dr. Reynolds had shown that it had the effect of reducing the uterine musculature to a quiescent state and that it does this with or without the ovaries. In other words, the effective substance in the injected urine acts directly on the uterus itself and the ovary is not necessary as an intermediate agent. It then became important to know if the same held true for extracts of the anterior lobe. The necessary data to answer this affirmatively have been secured by Dr. Reynolds. He finds that alkaline extracts of the anterior lobe of the pituitary gland exactly parallels the effect of injection of extracts of human urine of pregnancy.

An important study on the effect of corpus luteum extracts on uterine motility was made by Dr. Reynolds in collaboration with Dr. W. M. Allen of the University of Rochester. Dr. Allen was able to contribute his valuable experience in the preparation of an improved extract of the corpus luteum containing in refined form the hormone designated as progestin. This extract produces in the castrated rabbit cytological and physiological conditions identical with those found during pregnancy.

Having an accurately assayed progestin-containing extract it was possible to test its inhibitory power on uterine motility in counteraction to the uterine stimulator theelin. In the first place it was shown by Dr. Reynolds and Dr. Allen that injection of their progestin-containing extract into rabbits showing normal oestrous motility results in reduction of this motility, and if the injections are continued for two or three days the motility entirely disappears, to return again a few days after the injections are discontinued. In the next place it was shown that in the castrated rabbit, where uterine motility can be produced by injection of theelin, this response is prevented by injection of a progestin-containing extract of the corpus luteum. And finally it was shown that the injection of theelin during the first few days after mating prevents the proliferative changes in the endometrium but does not prevent the formation of normal corpora lutea, with the result that the motility of the uterus is reduced as usual. If, however, the same amount of theelin is given to unmated rabbits, and having no corpora lutea, the normal oestrous motility is maintained. Thus in these two ovarian extracts, theelin the stimulator and progestin the depressor, we have two directly contraposed agencies. This appears to simplify the endocrinology of the ovary, but if the common biological preference for complexity pre-

vails in this organ, we may expect this ovarian duality to be replaced by an ovarian triangle and that in turn by a quadrilateral and so on.

Another group of experiments in which uterine motility was utilized as a test of hormonal activity was carried out by Dr. Reynolds in collaboration with Dr. W. M. Firor of the Johns Hopkins Hospital. The hypophysis was removed on the fifth or sixth day of pregnancy in the rabbit, with the result that within 48 hours after the operation the animal had lost power to inhibit uterine contractions induced by injections of theelin, that is, the corpora lutea had become ineffective. Corpora evidently require an intact hypophysis. In another series of experiments the hypophysis was removed 35 minutes after mating, which prevented the ovulation normally following at the ninth hour. They then injected in these same animals urine of pregnancy which promptly induced ovulation. They have also studied the histological changes in the uterus and ovaries of hypophysectomized rabbits following repeated injections of theelin, also of anterior lobe extracts.

DYSMENORRHEA

Dr. E. Novak and Dr. S. R. M. Reynolds through combination of clinical experience and experimental observations on rabbits have obtained evidence indicating that the immediate cause of the very prevalent and troublesome condition known as dysmenorrhea is the exaggerated and painful contractility of the uterine musculature. Uterine contractions were studied in rabbits in which a balloon inserted in a uterine fistula recorded the muscular behavior. In this way it was confirmed that folliculin, the female sex hormone, is the essential stimulant of uterine motility and appears to be the only endocrine preparation possessing this property. In referring to Dr. Reynolds' studies in the report of last year the female sex hormone was referred to as "œstrin." Since then Dr. Reynolds has accepted folliculin as the more appropriate designation. As an alternative, he also uses the term "theelin." In the rapidly growing science of endocrinology the law of survival of the fittest has not yet had time to operate on the confusing matter of terminology.

It was found that either onset of corpus luteum activity or injection of progesterin, a corpus luteum derivative, has an effect directly contrary to folliculin, in that it quiets uterine muscle. The same can be said for prolactin, a pituitary derivative found in the urine of pregnant women. Dr. Novak and Dr. Reynolds conclude that these phenomena which can be demonstrated in the rabbit can be applied to man. On this basis they explain dysmenorrhea as an endocrine imbalance between the uterine motility factors—especially female sex hormone the stimulant and progesterin the depressor. In the normal cycle, progesterin from the corpus luteum inhibits uterine motility during the premenstrual stage, but if this fails to take place or if the female sex hormone is overactive there is produced excessive uterine contractions which in some women are the source of marked discomfort. As the physiology of these phenomena become better understood, a better basis will be provided for clinical relief.

PASSAGE OF HORMONES THROUGH PLACENTA

After Dr. G. B. Wislocki and Dr. F. F. Snyder had shown that a new ovulation can be superimposed in the pregnant rabbit, either by injection of extract of anterior lobe of the hypophysis of the cow or by injection of concentrated human urine of pregnancy, it became apparent that this made it possible to answer the question as to the passage of anterior lobe substance from fetus to mother. Using pregnant rabbits, these substances were injected with great precaution into the peritoneal cavity of the fetus and then some few days later the mother was opened under anesthesia so that the ovaries could be examined and the fetuses also examined as to whether they were still alive and the circulation intact. It was found that though the fetuses were living at the termination of the experiments, there had been no ovulation on the part of the mother. This demonstrated that the placental barrier withholds the passage of these hormonal products from the fetus to the mother, or else alters them so that they are no longer biologically effective. In a similar way Dr. Snyder had shown, while at the University of Rochester, that other glandular products, such as adrenalin, insulin, pituitrin and parathyrin, are not transmitted from fetus through the placenta to the mother.

ANATOMICAL STUDIES

VARIATIONS IN ARTERIAL PATTERNS

When one considers how sensitive the embryonic vascular system is in its adaptation to environmental requirements, it becomes remarkable that any uniformity in pattern emerges from the developmental stages. Certain major requirements, however, are usually repeated and thus the larger vessels have considerable constancy in animals of similar build. A study has recently been made by Dr. C. F. DeGaris in a human adult where a slight variation in the embryonic resolution of the aortic arches resulted in an extreme variation in the arm vessels. Usually the arm bud develops its principal supply from the subclavian, the segmental aortic branches dropping out. In the case of Dr. DeGaris these segmental twigs survived in the form of a remarkable subscapular augmentation of the axillary artery, so that much of the blood to the arm and axillary region came through the upper five intercostals, the blood in the subscapular artery flowing in the reversed direction. With this disturbance there were numerous variations in the arterial pattern throughout the arm.

Other studies on variations in vascular pattern are being made by Dr. DeGaris in the arteries at the base of the brain. In these he is tabulating the differences between negroes and white stock as seen in dissecting room material. In collaboration with Miss H. M. Carpenter he has also tabulated the arrangement of branches of the aortic arch as they occur in primates other than man. They have been able to make observations on a rather large series and representative of both prosimian and simian genera.

HOMOLOGIES IN FINS OF FISHES

Because of their importance to his studies of the shoulder architecture of mammals, Mr. A. Brazier Howell has turned his attention to homologies

in the paired fins of fishes. In doing this he has studied especially the innervation of the fin muscles, utilizing faradic stimulation of the nerve trunks as an additional means of determining their finer muscle relations. In the light of the observations made in this way he has been able to reanalyze the homologies of these structures.

The prevailing view that the paired vertebrate appendages must be either pectoral or pelvic in origin is rendered doubtful by Professor Howell. From the neuro-muscular relations demonstrated by him, it would now seem possible that paired appendages might appear in any situation along the branchioclacal line according to the functional requirements of locomotion, support and equilibration. In consequence, they may be pectoral in their homology, or pelvic, or migrated derivatives of either of these, or they may be entirely independent intermembranal elements. In his survey of recent and fossil fishes, Professor Howell finds representatives of these various combinations. In the cod for instance, he finds a pectoral fin for propulsion innervated by the first four spinal nerves, and a ventral fin for postural support innervated by the next three, with no pelvic representative whatever, and thus another ground plan has gone wrong.

Through the innervation of the fin muscles, Mr. Howell has traced the derivation of the muscular groups and their skeletal relationship in the dogfish and cod. His observations will be of value to the student of morphogenesis of the vertebrate appendages.

SPECIES VARIATIONS AND GENERIC DETERMINATION

In a recent review, Dr. A. H. Schultz has emphasized the constant tendency of the human body to vary in all its parts and he shows that these differences are not the influence of differing occupations, diets and other environmental factors, but are present at birth and can be recognized in the fetus. Whereas many of these variations are the result of the combination of diverse hereditary patterns in the parents, he finds in bilateral asymmetries and in single-ovum twins, a type of variation which may be regarded as a force in itself, existing in spite of heredity and environment, though modified by them. Some structures are more variable than others and they are the ones that are most rapidly undergoing modification. Without these variations, which Dr. Schultz has been profitably engaged in identifying, there could be no lasting change or evolution in our physical make-up. It would appear that anthropology is casting eyes at a field with which genetics is already partially oriented in terms of unstable genes and inheritance of asymmetries.

Incident to his observations on growth in primates, Dr. Schultz has had occasion to study the small black gibbon of West Sumatra and described as a dwarf Siamang, *Symphalangus klossii*. Basing his conclusion on a considerable amount of skeletal material and preserved bodies he proposes that this form be made a subgenus, *Brachitanytes* or "arm swinger." The anatomical characters in which it clearly differs from the subgenus *Hylodotes* are listed by him.

An important monograph on the saltatorial rodent *Dipodomys* has been prepared by Professor A. Brazier Howell. Interest in this animal arises in

its high degree of specialization of the locomotor mechanism, a comparative anatomical study of which Professor Howell has had under progress for a number of years. While a complete study of the myology and osteology of these rodents is included in his monograph, special attention is devoted to the details of the jumping mechanism and the alteration in the various parts of the body in adaptation to their saltatorial specialization. He includes in his study various forms of kangaroo mice and rats and his observations will have much of interest to the student of convergence.

A striking example of convergent structural adaptation is provided by sloths and the lorisine lemurs. Both of these groups have become adapted secondarily to a sluggish mode of arboreal life and the maintenance of clinging or suspension postures. The adaptive structural similarities shown by these generically widely separated forms have been studied by Dr. W. L. Straus jr. and Dr. G. B. Wislocki. In a previous study, as mentioned in my report of last year, these investigators described the rete mirabile or a peculiar type of vascular bundle which is common to these two groups. They have now extended their observations to other structural characteristics and relationships indicative of convergence. Among the similarities thus interpreted by them are an increase in relative length of the upper extremity; reduction of the tail; relative broadening of the chest; increase in the number of presacral vertebra and ribs; and blunting of the thoracolumbar and lengthening of cervical spinous processes. These characteristics are notably those adapted to their habitual postures and modes of progression rather than to the finer movements having to do with agility.

It has been found by Dr. W. L. Straus jr. that a high variability, and oftentimes asymmetry, exists in the number of renal papillæ among Primates and even within a single genus. A preliminary account of his observations has appeared. He finds that *Tarsius* may have one or several papillæ; lemurs appear to have but one; New World monkeys vary greatly, having from one to several and show bilateral asymmetry; a similar variation exists among Old World monkeys; whereas among the anthropoid apes, the kidneys were never observed to have more than a single papilla. Certainly the kidney doesn't promise to be of much help to the phylogenist.

NERVE SUPPLY OF URETER

A study of the innervation of the genito-urinary organs and particularly the nature of the nerve supply of the ureter has been published during the past year by Dr. L. R. Wharton of the Department of Gynecology, Johns Hopkins University. Owing to their clinical importance in ureteral disorders, Dr. Wharton during the past two years has been tracing the relation of the abdominal and pelvic sympathetic plexuses to the sheath of the ureter. Because of the intricacy of these structures there had been much doubt as to whether the ureter did or did not receive any innervation beyond that derived by extension into its territory of the intrinsic nerves of the kidney and bladder. By improved methods of dissection, he has been able to demonstrate that the ureter does receive an independent nerve supply. These nerves come from the lowest renal ganglion at the upper end of the spermatic plexus and from the abdominal sympathetics. It was found that

there is an intimate connection between the ureteral innervation and the plexuses supplying the ovaries, testes and parietal peritoneum which has a bearing on the clinical problem of spasmodic pain in these structures. Dr. Wharton has found that these nerves can be isolated in the course of surgical operations and ureteral denervation can be performed without interfering with the motor function of the ureter or causing other ureteral disturbance.

THE NERVOUS SYSTEM

During the past year the writer of this report has applied himself to a re-study of the development of the brain of the embryo chick, seeking by improved technique to verify the presence or absence of transitory metameric segmentation of the central nervous system. The nearest approach to metamerism was found to be that in the spinal region, but even there it appears to represent an adaptation to the somites lying alongside. Segmentation is evidently primary in the somites, which in the early stages induce this characteristic in the cord.

Instead of metamerism, the governing principle appears to be the adaptation of the central nervous system to the structures it serves. It is adapted to the body just as much as the body is adapted to it. In the early stages it is adapted to the simple embryonic requirements which are chiefly the muscle primordia. As the requirements of the organism become more complex, the nervous system keeps abreast. New subdivisions and modifying mechanisms in the central nervous system come into existence as a product of interaction between pioneer mechanisms and thus the successive appearance of the various nuclear masses and associated fiber-systems can be traced step by step until the final form of the brain is attained. In other words the neural tube at the start shows itself responsive at all levels to its environment. Where the environment is truly segmented, the tube takes on that character in some degree. At levels where the environment is branchiomic, the tube is found responding with appropriate branchiomic nerves. Where there are no environmental demands, the tube restricts itself to its own requirements. This is illustrated in the 3-mm. embryo (see accompanying sketch). Here one finds that where the mesoderm is segmented the neural axis conforms to that arrangement, whereas in the region of the facial processes and branchial bars there is supplied an appropriate set of cranial nerves. Farther forward the primary requirements are those of the visual and olfactory mechanisms, which obligations the brain meets adequately. On top of these there subsequently appear new centers and super-centers for the control, elaboration and coordination of the brain itself. As these find their place, the simpler embryonic form becomes converted into the final brain, and all of this occurs without the good offices of metamerism.

In the sense that the brain consists of different morphological parts, it is segmented. Embryologically these segments fall into different classes. First there is the near-metamerism occurring in the spinal region, the adaptation to the somites. Second, there is the branchial segmentation in adaptation to the condensed cell-masses that are to form the tissues and musculature of the maxillary, mandibular and throat regions which are thereby provided with branchiomic visceral cranial nerves. And finally, there are

the subdivisions of the neural wall associated with the development of definite brain parts. From the earliest stages the last are characterized by individuality of form and are not serial repetitions of a uniform pattern, and furthermore they vary among different animal classes and orders. If

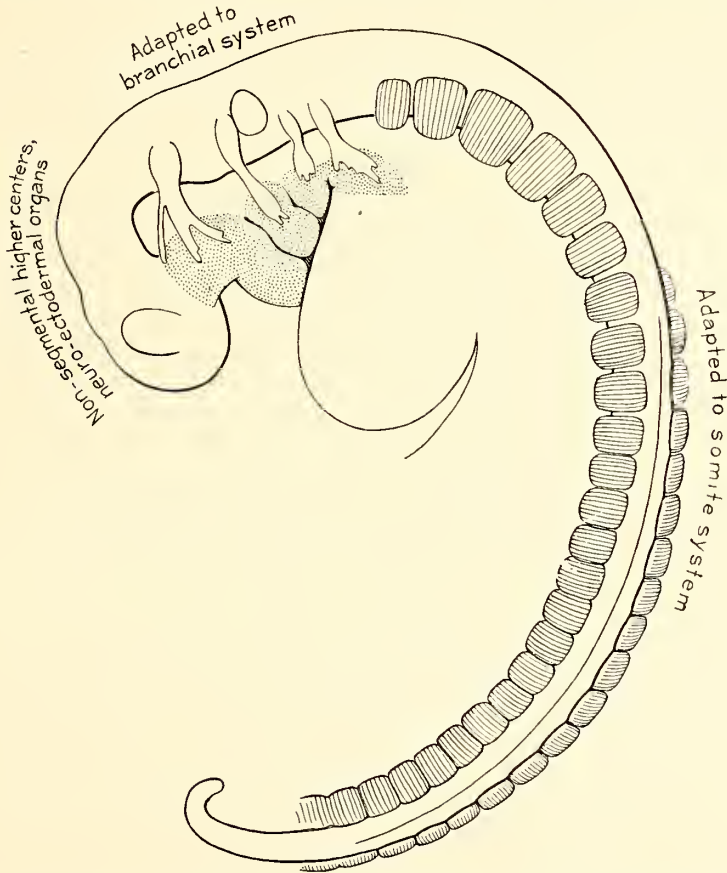


FIG. 1—The embryonic central nervous system adapts itself to the structures it serves, and where the environment is segmental it too takes on that character in some degree. Thus in the spinal region the metameric somites are supplied with segmental nerves imparting a segmental character to the cord. In the branchial region the condensed face and throat tissues receive nerves according to the disposition of their separate masses, giving a branchiomic character to this part of the brain. Otherwise those parts that constitute the bulk of the eventual brain are entirely free of segmentation. Human embryo, 25 somites, Carnegie Collection, No. 6097.

we refer to segmentation of the nervous system with the above implications it will probably not be as necessary to make compromises with demonstrable morphology as it has been in the past.

DEVELOPMENT OF NERVOUS CENTERS

In a Handbook chapter reviewing the development of centers in the spinal cord and brain, Dr. M. Hines has analyzed our present evidence regarding the correlation between structural and functional development. The structural characteristics studied include the development of pathways,

time of myelinization, separation of cell masses into layers, spacing of the individual cell, and the development of Nissl substance within the cytoplasm. On the whole, the completion of such anatomical characteristics are found to be a reliable indication of the capacity for function, but this does not require a causal relation. In fact education seems to play less part than first thought. Following the Coghill experience, Dr. Hines is inclined to regard the integrative mechanism developing first as a whole, followed by the development of larger and then smaller independent subdivisions. Correspondingly we find that the more finely controlled and separated purposeful movements develop last.

INNERVATION OF SKELETAL MUSCLE OF THE BOA CONSTRICTOR

In a boa constrictor which had been brought back by Dr. Wislocki on one of his visits to Central America, Dr. M. Hines has been able to study reptilian nerve-muscle relationship under most favorable circumstances. The animal was in good condition and it was possible to make a vital injection of methylene blue, which technique provides a picture of nerve endings more complete than is possible by any other method. The confusion that has existed between the reports of different observers seems to rest on their failure to see the whole picture. In such studies there is an advantage in utilizing small flattened muscles which can be examined on both sides and in which the relation of endings to each other and to their source of innervation can be followed, as was possible in the muscles selected in this case.

In the first place it was found that there is no evidence that the sympathetic nervous system contributes any innervation to the non-spindle fibers of the muscle. As for the spindle fibers there were very few non-medullated fibers seen and it is therefore very doubtful if the sympathetic system plays any role in the functioning of the spindle. This is in harmony with the degeneration experiments of Dr. Hines and Dr. Tower, a few years ago, in which the central connections of the nerve endings of the spindles were determined by sectioning the ventral and dorsal nerve roots with study of the subsequent degeneration.

When the innervation of skeletal muscle in the boa constrictor is compared with that of other reptiles, Dr. Hines finds that there is a great range of morphological variation, existing between the different orders and the different muscles of a particular species. That is, there appears to be no "reptilian" pattern. The complexity of the nerve ending appears to vary according to the differentiation of central control rather than according to a theoretical phylogenetic age of the muscles. In the particular skeletal muscles studied, the innervation was effected by motor end plates and by grape-like endings, partly epilemmal and partly hypolemmal. These different types were found on both granular and agranular muscle fibers, though the motor end plate was the more common terminal on the agranular fibers. As for the spindles, the equatorial ending is almost invariably single and with few exceptions this is also true of the polar terminals. The latter are usually epilemmal. In some instances they were found within the spindle capsule near the central ending.

REGENERATION IN THE SYMPATHETIC NERVOUS SYSTEM

Dr. S. S. Tower and Dr. C. P. Richter have found that in the resistance offered by the skin to the passage of a small constant electric current and in the presence or absence of action currents in the skin they have a more sensitive and a better quantitative index to the state of sympathetic function and sudomotor innervation than is provided by any other available test. They have taken advantage of this to determine the effect of lesion and the rate of regeneration in the sympathetic system. Their experiments with the preganglionic fibers were referred to in the report of last year. Since then their studies have been extended to the postganglionic fibers in cats. When these fibers are injured the damage is in general similar but also much greater than it was in the case of the preganglionic fibers. In the first place there is a complete and permanent obliteration of both sudomotor activity and of skin action currents, there being no sign of recovery in either of these functions as late as a year and a half after operation. As for skin resistance, it shows an initial rise of about a week, which is followed by a period lasting several months, during which the resistance retains on the average a high level and finally there is an abrupt decline with the skin resistance reaching a stable level, though definitely above the normal.

Histological examination revealed that lesions of the postganglionic fibers result in practically complete degeneration of the postganglionic neurons, with no possibility of regeneration. Apparently this is due to the nearness of the lesion to the cell body, and the operative interference with the blood supply may also contribute to the result. Under these conditions it is obvious why the suppression of the sudomotor activity and of skin action currents is permanent. It also explains why the skin resistance remains well above the normal level, assuming that the activity of the sweat glands is of prime importance for maintaining the extremely low level of normal skin resistance. That there is partial recovery in this regard predicates a readjustment which is non-nervous in its mechanism. Apparently the epithelial tissues have this capacity for compensation, and it is also possible that there is a vascular factor.

After having the data on preganglionic and postganglionic injury before them, Dr. Tower and Dr. Richter have arrived at the conclusion that the intact postganglionic mechanism, independent of the central nervous system, exerts a moderating influence on skin resistance, that is, here is the long-sought example of sympathetic ganglia serving as a center for integrative activity outside the central nervous system. Although the central nervous system controls skin resistance, as is evidenced by the immediate rise upon interruption of the pathway at any point, yet it can not be the total mechanism of control. Proof of this is provided by the difference in results between preganglionic and postganglionic section of this pathway. Whether the postganglionic mechanism exerts its influence by some axone type of reflex, or through the physical integrity of innervation preventing degeneration or some form of mysterious trophic control, or through some quite other means, awaits further study. It might be expected that its relative dryness would be an important element in the conductivity of the skin.

Another aspect of regeneration of nervous tissue has been contributed by Dr. H. G. Schwartz, who began his study at Princeton University. After removing portions of the cerebral ganglia in a series of earthworms, he has traced the source of the new ganglion cells and associated tissues that take their place. He finds that they do not arise from embryonic rests of neuroblasts from the remaining ganglia, but result from the proliferation and transformation of connective tissue cells. It is of particular embryological interest to meet with this example of mesodermal origin of nervous tissue, and these observations offer a significant warning to those who follow in blind allegiance the three-germ-layer analysis of the embryo.

The supporting framework of the new ganglia is supplied by the condensation of the extracellular connective tissue surrounding the new nerve cells. The replacement-ganglion cells in the form of connective tissue cells appear to invade the region and undergo proliferation. They therewith exhibit differentiation of their nucleus and cytoplasm including iron containing Nissl bodies and the development of an axone by which they become transformed into typical ganglion cells.

Two days after the operation there is a marked increase in the number of connective tissue cells, and on the fifth day differentiation has begun. The bulk of the ganglion mass is regenerated within three weeks, and at seventeen weeks the external morphology of the ganglia and associated nerve trunks resembles the normal. The proliferation of the nerve cells is completed by the ninth day as shown by the absence of mitosis thereafter. It is to be noted, however, that although the regenerated parts were morphologically normal, the operated worms would never thereafter burrow, even after seventeen weeks. They commonly crawled with the anterior part of their bodies raised. Thus we must conclude that their "behavior pattern" was not restored.

GRASPING REFLEX IN THE NEW-BORN MONKEY

The grasping response has been studied by Dr. C. P. Richter in a series of young monkeys from birth to the time of disappearance of the reflex during the third month. With one arm and the legs bandaged together the monkey is allowed to hang by one hand from a bar suspended above a net in which he is caught on release of his hold. Records were taken about every other day. Though showing variations from day to day and between individuals, it was found that the reflex is much stronger in the new-born monkey than in the new-born human infant. The monkey with one hand hung for over thirty minutes as compared with the human record of two and a half minutes, hanging with both hands. As between the right and left hand the series was not large enough to arrive at a difference. In the five animals studied it appeared to be equally strong on the two sides.

The reflex increases in strength after birth and reaches its maximum between the 15th and 38th day. It disappeared in four animals on the following days, 41, 65, 71 and 71. In the fifth it was still present on the 83d day, when the experiment was discontinued. At that time it was gradually diminishing, and the higher centers were beginning to assume domination as had happened earlier in the more precocious animals. Since

making these observations Dr. Richter has given his attention to the recurrence of this reflex in adult monkeys following experimental lesions of the brain and the administration of various drugs.

THE CEREBROSPINAL FLUID

Of the different fluid systems of the body, the blood vascular system is the best understood. The lymphatic system could be placed next. Compared with the first two, the fluid that bathes the tissues and membranes of the central nervous system has been the most obscure, and it is only in recent years that definite information has been obtained regarding its source, its amount and the manner of its function. At the same time it has become apparent that this cerebrospinal fluid plays an important and particular part in certain serious diseases and in consequence all phases of its structural and physiological characteristics have taken on an increased importance. The studies of Dr. Lewis H. Weed and his coworkers have been frequently mentioned in these reports. They have concerned the histology and functions of the brain membranes and more particularly the physical aspects of change in volume of the cerebrospinal fluid and the factors regulating the cerebrospinal fluid pressure. These studies have opened a new field of inquiry, including the significance of negative pressures within the cranium of erect mammals. They have firmly established the nature of the cavity within which the nervous system is contained and sheltered from atmospheric pressures, so important to the intricate regulation of its blood supply. The manner in which the constancy of volume of the dural sac is maintained has been demonstrated and during the past year they have clearly revealed the element of elasticity which is essential to the system and the movements of its fluid.

ELASTICITY OF THE DURAL SAC

The observations made with the tilting table had demonstrated that when a dog or cat is abruptly changed from the horizontal to vertical positions, a measurable alteration occurs in the pressure of the cerebrospinal fluid and there is an actual dislocation of the fluid. From this it was apparent that the membranes and vascular channels surrounding the central nervous system must possess an elastic quality, although the cranial walls and vertebrate canal otherwise form a rigid inclosure. Such an elastic element is necessary to permit the shifting of fluid from one region of the dural cavity to another without change in volume.

In continuing these experiments it was found by Doctors L. B. Flexner, J. H. Clark and L. H. Weed that the difference in volume of displaced fluid has a definite relation to the difference in pressure-change. That is, when the cerebrospinal fluid pressure is recorded in the occipital region in experiments where there are various amounts of volume-alteration, through use of manometer bores of different sizes, it is found that with abrupt tiltings the difference in volume of displaced fluid in any one animal has a definite relation to the difference in pressure-change. This relationship is expressed by them by a fraction in which the difference in volume-change on tilting is divided by the difference in pressure-change. The quotient was

found fairly constant in dogs of the same size (6 to 7 kgm.) having an average value of 0.17. It was thus seen that the elasticity of the dural sac and its contents is subject to the application of the physical laws of an elastic system, and that the coefficient of elasticity can be obtained by substituting for stress the change in pressure and for strain the change in volume divided by the original volume. When this was calculated for dogs of different sizes, weights and ages the unexpected discovery was made that in immature animals the power of the cerebrospinal system to resist deformation of its contents is greater than in fully adult and old animals, that is, they have a larger coefficient of elasticity. The values in dynes per square centimeter in the series of dogs studied were found to be: immature dogs, 4.63 to 4.52×10^5 ; young adults, 4.39 to 4.09×10^5 ; adults, 4.03 to 4.02×10^5 ; old dogs, 3.84 to 3.78×10^5 . These results appear to be explained by the fact that the elasticity of the system is not limited to the intrinsic distensibility and collapsibility of the dural sac, but also involves the important factors of vascular adjustment and age-changes in the finer structure of the intradural and epidural tissues.

Dr. Weed and Dr. Flexner forthwith extended these observations to include cats and monkeys, and it was found that they too show a gradual decrease in the coefficient of elasticity as one progresses from the juvenile to the adult and old animals. It is therefore probable that the degree of the cerebrospinal elasticity and its change with age are properties common to mammals in general. By including the macaque in their series, they introduced the factor of erect posture. The question could be answered in the negative as to whether the adoption of the erect posture has not been accompanied by development of new mechanisms for protection of the nervous system against the hydrostatic pressures in the cerebrospinal fluid which the vertical posture imposes on the animal. The coefficients of elasticity were essentially the same in the macaque, accustomed to an erect posture, as in the dog, whose habitual posture is horizontal. The same is doubtless true for man.

RATE OF FORMATION OF CEREBROSPINAL FLUID

By perfecting the technique for its determination, Dr. L. B. Flexner with the assistance of Dr. H. Winters has obtained new data on the rate of formation of the cerebrospinal fluid. Our knowledge of this has heretofore been largely conjectural. These investigators have at least been able to demonstrate in etherized cats that the average rate of flow of cerebrospinal fluid from the aqueduct of Sylvius is 12 c.c. per day. The rate in a series of 13 adult cats varied between 9 c.c. and 16 c.c. of fluid per day. If to this there is added the fluid secreted by the choroid plexus of the fourth ventricle, based on the proportional weight of the plexus, which is one-fourth that of the other plexuses, the total ventricular average production of fluid per day would be 15 c.c. Previous estimates had been very much higher than this.

In order to measure, under normal intraventricular pressure, the amount of cerebrospinal fluid leaving the aqueduct over a period of several hours, it was necessary to have a water-tight connection at the outlet of the aqueduct and a device which allowed measurement of changes in fluid-volume

at known pressures. These requirements were met by a catheter fitted to the rostral end of the ventricle by a dilatable balloon. The amount of fluid leaving the catheter was measured by a bubble-manometer. With this method one records only the fluid formed within the ventricles, secreted by the choroid plexuses. There remains the possibility of additional fluid normally escaping from the perivascular spaces and from the blood-vessels of the subarachnoid space. There is scant evidence of this, however, and the amount, if any, is regarded as negligible. Their relation to absorption is quite another matter and concerning which there remains much to be learned.

It was found that the rate of flow may be constant for several hours, or an active flow may alternate with periods of rest, in regular cycles, or finally the flow may present various irregularities. By recording the intracranial arterial and venous pressures along with the rate of cerebrospinal fluid-escape they were able to show that deviations in the rate of flow in some cases are correlated with intracranial venous pressure-changes. Such deviations are probably the result of ventricular volume change, rather than due to actual variations in the rate of formation of cerebrospinal fluid. There are, however, other variations in the flow not associated with changes in blood pressure and which may last for long periods of time. These appear to be due to actual variations in the rate of formation of fluid, the explanation of which remains to be found.

DEPARTMENT OF GENETICS¹

C. B. DAVENPORT, DIRECTOR

GENERAL STATEMENT

The study of heredity is proceeding ever toward more fundamental phenomena. In Galton's day it was a study of the family incidence of certain traits. The plant experimenters of a century ago were, like the late Mr. Burbank, concerned with the transfer of characteristics by hybridization, by the uniting of alien germ cells. As biological knowledge grew, the problem of the mechanism of heredity was transferred from the germ cells to the nuclei of the cells and especially to the chromosomes. While biological philosophers had long agreed that there must be a finer unit—the gene—it has been scientifically studied for only about the last twenty years.

Concerning the nature of the gene, diverse views exist. One view is that, though simple, it varies in size in different strains. When the gene is large a "strong" well-developed character arises; when small the character is more weakly expressed. On this view the mutations in a gene are purely quantitative. Another view regards the gene as made up of gene elements or "genomeres," which may or may not be chemically the same. Still another view is that the gene consists of a large molecule to which the same side-chain of molecular groups is attached several times. As between the quantitative theory of differing factors at the same locus and the various theories that call for a qualitative difference between these factors, the observations of Demerec throw the weight of evidence toward the qualitative theory, inasmuch as the various mutations play qualitatively distinct roles. From this point of view the gene is a compound molecule, the stripping off of whose molecular groups causes changes partly of a quantitative, partly of a qualitative, nature. The analogy of this behavior to that of certain better-studied organic molecules is somewhat close. It is thought most probable that each gene in the cell is a substance that directly or indirectly produces enzymes, each of which stimulates differential growth and development of a specific kind.

The foregoing considerations bear upon the problem of the size of the gene. Our former colleague, the late Dr. Belling, considered the small paired particles that can be seen strung along the length of the chromosome in its attenuated stage as such genes. They lie close to the limit of resolvability, when viewed by ordinary white light. The visible ones vary in size, and apparently still smaller ones can be seen by ultra-violet photography. They are of the order of one-fifth of a micron (or 8 millionths of an inch) in diameter, and smaller. Certain experimental work has led some geneticists to conclude that the real genes are about one-tenth of the diameter of Belling's "genes." Since the latter agree with theory in number, though not in size, it seems probable that the ultimate genes lie imbedded in the heart of Belling's genes—a view to which Belling had come shortly before his death.

¹ Address: Cold Spring Harbor, Long Island, New York.

Scores of problems cluster around the gene. To state that it acts as a true catalyst does not carry us far, for each kind of gene plays a particular role in development, affecting the development of particular organs. The great problem is how, out of the apparently full equipment of genes, do just those that influence the specific nature of the cell become functional at the right time and place.

The investigation of the gene is of the highest importance not only for an understanding of how the body develops and becomes specialized or differentiated in its various parts, but also for an understanding of the nature of the ultimate living substance. When we understand the structure of the gene we shall know the essential difference between living and non-living matter. The geneticist should shortly be in a position to aid the chemist in getting at the ultimate nature of living matter and especially must both co-operate in the solution of the problem of the fundamental property of the living molecule, namely its capacity for dividing indefinitely with retention of all of its qualities. For upon this property depends all agriculture and animal husbandry—depends all life itself. Before the self-dividing molecule had been evolved, this was a lifeless world; unless it has been evolved in other planets, they are lifeless still. The living, dividing molecule, of which the gene is a special sort, is the great upbuilding agency in a universe that is running down. Its capacity for creation is due to the genes whose ability to increase living matter is limited only by the conditions imposed by the non-living world. For the genes create living matter out of the non-living material, while periodically that which they have created is returned to its source for new generations to feed upon. Indeed, it is not sufficient that the gene multiply, it must forever change and build up a new and different generation to keep pace with changing cosmic conditions, and, as opportunity arises, to meet those conditions more effectively. Of what makes the gene change we have a conception; but of what makes it divide we have no inkling; we only know division to be its unique and fundamental nature.

All the personnel of this Department cooperated in the Sixth International Congress of Genetics held at Ithaca last August, and with the Third International Congress of Eugenics held in New York City the same month. Especial mention may be made of the work of Laughlin in organizing and installing the Eugenics Exhibit at the American Museum of Natural History and of Demerec in getting together the Genetical Exhibit at Ithaca.

On Sunday, August 21, 1932, the foreign visitors to the Congresses were received at Cold Spring Harbor and shown the work of the Department. Neighbors invited guests to their near-by country homes for luncheon. The American Museum was host to delegates to both Congresses. During the months following the Congresses we had for a longer or shorter period as research guests Dr. Tage Kemp of Copenhagen, Dr. and Mrs. Timoféeff-Ressovsky of Berlin and Dr. Curt Stern of Dahlem.

The Institution has suffered severe losses by the death of persons long associated with this Department. Dr. John Belling, who was with us from 1920 to 1929 died in Berkeley, California, February 27, 1933. Personally shy and retiring, his scientific work was characterized by a boldness that would have been regarded as rashness had events not proved the accuracy of his

observations and the flawlessness of his deductions. His was an unusual combination of scientist, philosopher and poet. The impress of his genius will be felt on genetics for a generation to come.

Miss Julia I. Goodrich, who served for twenty-seven years as secretary of the Department, died on January 21, and George H. Clafin, for twenty years chief clerk, died May 13.

DETAILED REPORTS ON CURRENT INVESTIGATIONS

THE GENE

EXPERIMENTS ON MOLECULAR STRUCTURE

That development of the organism is controlled from the inside by means of definite particles of different kinds that play a differential role in development is a conception that is at least 100 years old. But in the past 25 years the pangenes of Darwin and the genes of Johansen have taken a more concrete form. They can now be counted, located, measured, differentiated. But of their more intimate nature or structure we have little knowledge. In this department it is especially Demerec whose work has led to the formulation of a working hypothesis of the nature of the gene. The genes are experimentally proved to be minute particles; probably single organic molecules—an assumption not, however, necessary to his concept. If genes are large organic molecules, they most probably consist of a number of interconnected molecular groups. This conclusion is supported by the facts of multiple allelomorphs—genes of differing but related qualities and occupying, in different biotypes, the same locus in the chromosome.

In the *miniature* locus of *Drosophila virilis* ten allelomorphs are known which can be arranged into a two dimensional series as follows:

mt-1	mt-3	mt-2	mt-5	mt-4	wild-type
	alpha		alpha		
	beta		beta		
	gamma		gamma		

Allelomorphs are arranged in the horizontal line at the top according to size of the wings, and in the vertical column according to the degree of stability (mt-3 and mt-5 allelomorphs being unstable). There is a much closer connection between the allelomorphs of any one vertical group than between the allelomorphs of the horizontal group, since a transformation of one allelomorph into another in the vertical group occurs rather frequently and such a transformation has never been observed for the allelomorphs of the horizontal groups. This evidence suggests that changes producing different allelomorphs are independent of each other and indicates that they might arise by changes in different groups of one gene molecule.

This hypothesis is being tested by Demerec who is studying the changes produced by X-rays in the white locus of *Drosophila melanogaster*. White eye may be obtained from the wild type (red eye) as well as from other allelomorphs of the white locus, such as eosin, apricot, cherry and blood. Now, if each of the 11 known allelomorphs of white is produced by a change occurring in a different group of the gene molecule, it is to be expected that

whites obtained from different allelomorphs will be different. The white derived from wild-type would involve a change in the group responsible for white: the white derived from eosin would have in addition to the change in the white group also a change in the group responsible for eosin, etc. A reversion, therefore, from white derived from the wild-type should be red, from white derived from eosin should be eosin, and from white derived from apricot should be apricot.

The testing of this hypothesis has not been easy. To secure reversion from white required a very large number of individuals subjected to a heavy dosage. The treated male was mated to an attached X female. The dosage used was 2500 and 3000 r-units and was so heavy that it caused a high degree of sterility among the treated flies. The results of this prolonged experiment are given in the following table:

Changes observed in the white locus of Drosophila melanogaster

Origin	Changes to white		Reversions from white		
	Number of		Number of		Appearance of reversions
	Males	Changes	Males	Reversions	
White stock.....			12,098	0	
Wild-type.....	3,910	5	33,638	0	
Apricot.....	2,446	4	10,495	2	1 apricot; 1 darker eosin
Eosin.....	2,014	8	15,035	1	
Cherry.....	783	2	4,918	0	
Blood.....	1,098	1	.....	.....

Of the three reversions from white shown in the table, two have been tested so far and found not to be due to a change in the white locus but to changes in other loci, located in autosomes. This suggests that the white gene could more easily be induced to produce color by changes occurring in the gene complex (made up of associated genes) rather than in the principal gene itself. The data indicate, furthermore, that if the allelomorphs are due to changes in various groups of a gene molecule, the changes occurring in different groups might give a similar phenotypic effect. It is obvious that a method that induces sterility and requires 25,000 male offspring to afford 1 reversion from white will yield the sought answer only on prolonged search.

THE ROLE OF THE GENE IN VITAL FUNCTIONS

It has been found that a great majority of changes observed in known loci of *D. melanogaster* are lethal; also the loss of a small region of a chromosome (deficiency) has a lethal effect. These two observations suggest that a lethal in a known locus might be due to an elimination of the gene; *i.e.* a deficiency in a single locus has a lethal effect on the organism. Demerec has tested this conclusion. He used females of a race that frequently eliminates an X-chromosome in the somatic cells of females and mated them with X-rayed yellow males, a portion of whose sperm carries

lethals induced by X-ray treatment. In cells of any resulting females in which the X-chromosome has been eliminated, yellow spots will appear. But if the yellow-bearing chromosome carries a lethal factor, which prevents altogether the development of those cells with eliminated (X) chromosome, then yellow spots on such females will not appear. Actually there were less than half as many lethals among the females with spots as among the females without spots, since the latter carried cell-lethals. The results indicate that 56 per cent of all lethals are cell-lethals. The conclusion seems inescapable that a full complement of at least certain genes is essential for the life of the cell. From these facts Demerec draws an important conclusion. If a strain of organism possesses only a few genes not present in another strain, that fact would cause a high degree of sterility among the offspring produced by crossing these two strains. Even a difference in one locus of the type described by Patterson as "viability gene" would be sufficient to produce complete incompatibility between two lines, one possessing the gene and the other not possessing it. Such a difference would be sufficient for the formation of a new species.

UNSTABLE MINIATURE-5 GENE

As indicated above, unstable miniature-5 (which was described in Year Book No. 30 and which is an allelomorph in the miniature series, having a somewhat longer wing than miniature-3) shows 3 allelomorphic forms, alpha, beta and gamma. Modifying factors which stimulate the rate of change in miniature-3 affect similarly the rate of change in the miniature-5 gene.

EFFECT OF X-RAYS ON THE RATE OF CHANGE OF THE UNSTABLE MINIATURE-3 GENE

The material carrying miniature-3 alpha and gamma was X-rayed at different stages of larval development; dosage about 2000 r-units. The rate of change in the unstable miniature-3 gene was not significantly affected.

SPINDLE-FIBER ATTACHMENT OF THE X-CHROMOSOME OF DROSOPHILA VIRILIS

In completion of the work described in Year Book No. 30 (p. 48), Demerec shows that the percentage of equational non-disjunctions diminishes markedly toward the end of the chromosome that contains the bobbed gene, and draws the conclusion that the attachment of the spindle fiber (an important bit of the machinery of chromosomal division) is located in that region.

The loci studied, their location, and the percentage of equational non-disjunctions observed are as follows: scute, 3, $12/45=26.7$ per cent; cross-veinless, 25.5, $14/45=31.1$ per cent; miniature, 72.1, $17/45=37.8$ per cent; small bristles, 138.8, $13/45=28.9$ per cent; apricot, 137, $10/38=26.3$ per cent; ragged, 159, $10/62=16.1$ per cent and bobbed, 174, $1/24=4/2$ per cent.

CHROMOSOME STUDIES

UNBALANCED HAPLOID

While the genes individually and collectively are the agents of the species that direct the development of the individual, it is not sufficient that they should be in the cell; it is essential that they be grouped in the nucleus in definite fashion so that they may be transmitted from mother to daughter

cells in an orderly way and so that they may come into functioning at the proper time and place. The chromosomes are, as has long been known, paired. The members of a pair have nearly the same genes arranged in the same order. In the maturing of the germ cells and in some somatic cells, like chromosomes pair, lying side by side, and with corresponding genes opposite each other. Thus, like poles are together, wherein the attraction between chromosomes differs from that between magnets.

From these text-book standards, *Daturas* show many instructive departures. In the first place instead of the typical 12 pairs of chromosomes (the diploid condition) some *Daturas* show only 12 single chromosomes (the haploid condition). Such haploids may grow, though not vigorously, and may flower, but ordinarily do not reproduce. This year Blakeslee has found two cases of a new type of chromosomal mutant; a haploid with 1 extra chromosome, making 13 in all. The first is probably a $1n + 7.7$ type. The mother was a $2n + 7.7$ and the modified haploid probably arose parthenogenetically with the secondary 7.7 chromosome extra. The chromosomal constitution was inferred from the somatic appearance of the plant and confirmed by cytological study. Though the plant is weak and may not survive to reproduce, it is important as revealing the greatest unbalance, 2 extra halves to 12 normal chromosomes, so far found in a *Datura* plant. The second case showed 13 chromosomes in pollen mother cells and in somatic tissue of the bud, but cells of the root tip showed a reversion to the $2n$ condition. Perhaps for this reason, as well as because of its lessened unbalance, in comparison with the first modified haploid, it is a relatively vigorous plant. It was the offspring of a $2n + 15.15$ female parent which was heterozygous for the interchanged chromosomes 11.15 and 12.16 of Prime Type 20.

That chromosomal irregularities may occur in other species of *Datura* besides *stramonium* is demonstrated by our recent finding of tetraploids in both *D. ferox* and *D. pruinosa*, and a haploid in the latter.

PRIME TYPES (PT'S)

These are strains of *D. stramonium* with $2n$ chromosomes that differ not in the genes but in their arrangement in the chromosomes. The collection of prime types corresponds to a printer's font of type since it is a source of modified chromosomes with which it is possible to make up $2n + 1$ tertiaries and compensating types, as well as pure-breeding chromosomal types. Whereas last year Blakeslee reported 57 prime types in 33 of which one or both of the modified chromosomes were known, this year he is able to report a total of 87 prime types in 55 of which one or both modified chromosomes have been determined. The kinds of chromosomal modifications involved are of three types. Nearly two-thirds have been due to segmental interchange, about one-fifth to simple translocation of gene groups and slightly over a tenth to interchange between "humps" attached to the ends of chromosomes. It is in the latter two types that bad pollen is most frequently found.

Prime types are used as chromosomal testers with which to identify the ends of chromosomes by noting their terminal attachments in meiosis. At

present Blakeslee has more than one prime type tester for each of the 12 chromosomes.

COMPENSATING TYPES

Compensating types, in which parts of two modified chromosomes compensate to form the equivalent of a single normal chromosome, are of value in locating genes and in retaining a single chromosome or chromosomal group during the process of back crossing. It is for this reason that we have been attempting through combining prime types to establish a complete series of compensating types which would compensate for each of the 12 chromosomes. So far we have succeeded in making up compensating types that will take care of all except 3 chromosomes.

SYNTHESIZED PURE-BREEDING TYPES

Whenever the cells of the plant carry, in addition to the normal (doubled) equipment of genes, an additional set of genes inhabiting a fragment of a chromosome firmly joined to another chromosome or chromosome fragment essential to the existence of the gametophyte, then, due to these excess genes, the plant is somatically different. If the chromosomes, including the extra inseparable fragment, are all paired, then a pure-breeding type has been synthesized. The prime types give the key to the process, inasmuch as they afford composite chromosomes, with firmly united fragments, and also others with free fragments which may compensate with one of the components of the composite. When, as is not always the case, the extra chromosomal material is transmitted by the pollen, a race may be established that will breed true.

During the year under review, a plant has been built up out of two prime types, of which one had a free .24 fragment and the other a 23.14 chromosome. The abnormal chromosomes of this plant have the composition: $\left(\frac{.24}{23.14}\right)_2$. It is homozygous for the extra .14 half and consequently is expected to breed true. It is hoped to develop further such true-breeding types.

SPECIES IN NATURE

One of the main objectives of the *Datura* work is an understanding of the nature and origin of species as they occur in nature. The frequency of interchange of chromosomal fragments in *D. stramonium* and the relation of this phenomenon to the formation of new pure-breeding types has led to the hypothesis that segmental interchange has accompanied the changes responsible for the formation of species in the genus *Datura*.

Cryptic types (resulting from segmental interchange) have indeed been identified in all the species of the genus in which three or more races have been tested; namely, *D. stramonium*, *D. quercifolia*, *D. leichardtii*, *D. meteloides*, *D. innoxia* and *D. metel*. The conclusion is accordingly drawn that segmental interchange leading to intraspecific races with modified chromosomes has commonly occurred within the genus *Datura*. This subject is being further investigated.

Inter-specific chromosomal differences also are being studied. Here, a single race is chosen as standard for each species in terms of which differ-

ences between it and similar standard testers in other species can be interpreted. A report was made last year of the findings in three species of the stramonium group (*D. stramonium*, *D. ferox* and *D. quercifolia*). This year results were obtained with *D. leichardtii*. The tester race of this species, by interchange between the 1·2 and 17·18 chromosomes and between the 11·12 and 15·16 chromosomes, has (in comparison with our standard line 1 of *D. stramonium*) the modified chromosomes 1·18, 2·17, 11·16 and 12·15. The 1·18 and 2·17 chromosomes are similar in end arrangement to those of the "B" race of *D. stramonium*.

D. leichardtii will cross with the species *D. innoxia*, *D. meteloides* and *D. pruinosa*, all of which belong to the *meteloides* group. They apparently will not cross directly with *D. stramonium*. *D. leichardtii* which has been hybridized with *stramonium* is therefore used as a bridging form to which hybrids with these other species can be back crossed and ultimately related indirectly to our final standard Line 1 of *D. stramonium*. This method necessitates the use of tester races intermediate between *stramonium* and *leichardtii*. Such testers are being gradually established and through their use we hope before long to be able to report upon the chromosomal constitution of these other species.

One species of the *meteloides* group, *D. discolor*, has been found capable of crossing with *D. stramonium* when the former is used as a pollen parent. It should be possible, therefore, to make direct determination of the ends of its modified chromosomes by study of the chromosome connections in hybrids with the various testers of *D. stramonium*. Preliminary study by Dr. Bergner indicates that the chromosomes of *D. discolor* differ from those of *D. stramonium* by a number of interchanges. The leaf characters of the hybrids, however, do not differ widely from those of *D. stramonium*. It should be possible, therefore, to recognize compensating types among the hybrid offspring and, provided the hybrids have adequate pollen, it should be possible by continued back crosses to the appropriate compensating types to produce races with all *stramonium* chromosomes except for the chromosome or chromosomal group protected by the compensating types.

MUTATION IN DATURA

Genes, of which we reported a considerable number in the last Year Book, are in process of being located in particular chromosomes by a variety of methods. One of especial interest may be mentioned at this time. It causes a doubling of chromosomes at meiosis, through the formation of dyads instead of tetrads of pollengrains. A "dyad" plant when selfed gives rise to dyad tetraploids in which the somatic tissue is $4n$ and the pollen grains have 48 chromosomes. Among the offspring of a tetraploid dyad, Miss Satina, who has been studying the cytology of this type, has made a count of about 72 chromosomes in somatic tissue of a bud. The plant is of weak growth but apparently represents a hexaploid ($6n$).

The formation of new genes by spontaneous mutation has been rare in *Datura*, although gene mutation can be readily induced by radiation and possibly by other stimuli. A series was started this summer to test the possible influence of age of seed upon mutation rate following the recent report

of Navashin, that more chromosomal abnormalities were found in root tips of plants grown from old seed.

Among effects of radiation treatment, those showing in the pollen are perhaps the most frequent. They include both the results of single genes and of chromosomal abnormalities. Pollen abortion can be used to advantage, therefore, as an index of the mutation rate, especially since the majority of pollen genes show in the individual grains affected and thus give an advantage of a generation over recessive genes which cause changes in somatic tissue. Dr. Cartledge, who has charge of the work in pollen abortion, has found 4.5 per cent pollen abnormalities in about 500 plants from seed 10 to 5½ years old and only 0.5 per cent abnormalities in about 1000 controls which came from seed 3½ to 1 year old. The older seed had been stored in the second floor of the main building, in the basement of which, about 32 feet away, an X-ray machine has been in operation since the summer of 1928. The machine has been enclosed in a ⅛ inch sheet of lead since the spring of 1930. The higher rate of mutation in the old seed is undoubtedly significant. Whether stray radiation from the X-ray machine in a distant part of the same building could have been at all responsible for the increased mutation rate is being tested by new plantings.

SOMATIC MUTATION IN *DROSOPHILA*

That mutations occur in somatic cells giving rise to "mosaic" individuals such as are illustrated by variegated plants has long been known, and they have been intensively studied by Demerec in the flowers of the *Delphinium*. Mosaics have been described in *Drosophila* also. Their nature has been uncertain. Dr. Curt Stern, while a guest at this Department during the latter part of the year under review, has made experiments on this subject in *Drosophila*. He finds that the spots which differ in appearance and genetic constitution from the surrounding tissues are not to be explained by mutation in the somatic cells, but by the disappearance of chromosomal parts with their genes. The experiments that he has made lead him to the conclusion that this disappearance is brought about by an exchange of parts between homologous chromosomes and by a subsequent segregation of these chromosomes. "These processes are similar to the well-studied processes of chromosome behavior in germ cells, but had not been known to occur in body cells."

FACTOR INTERACTION IN *DROSOPHILA VIRILIS*

Collaborating with Demerec, Mr. G. A. Lebedeff has completed a series of experiments showing extensive changes in the phenotype due to interaction of various genes. He has studied particularly the recessive genes: ruffled (*ru*), which makes tips of dorso-central bristles and hairs adjacent to them to be curled forward and the abdomen telescoped; and shaggy (*sh*), which causes hairs of the abdomen to be irregular. Also the dominant genes: rounded (*R*), which produces truncate wings and in a few instances makes dorso-central bristles curled; clipped (*Cl*), which makes the posterior end of both wings cut off; and beaded (*Bd*), which makes the margin of the wings scalloped. The new types appearing as a result of interaction in crosses involving these genes are indicated in the accompanying diagram.

These studies indicate the important role played by genetic environment upon the phenotypic expression of the gene. In a particular environment the ruffled gene, for example, produces only curling of dorso-central bristles and adjacent hairs, while under other conditions the same gene may produce exaggerated curling of bristles and hairs, different types of vortex character and short spread and roofed wings.

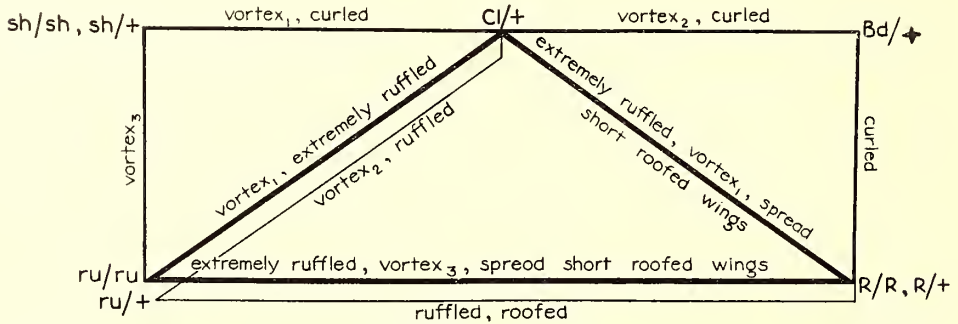


FIG. 1—New characteristics appearing in crosses involving five genes as the result of the interaction between these genes.

SOME NEW GENES IN DROSOPHILA VIRILIS

A dominant in the second chromosome, which causes all longitudinal wing veins to expand into deltas where they join the wing margin has been called delta (D). It is located 19.7 units from puffed and 37.75 from barbed. A new recessive in the third chromosome is intersex (ix) which, in the homozygous condition, changes females into intersexes. Another new gene, located in the third chromosome and a semidominant, when homozygous, kills about 75 per cent of males and about 50 per cent of the females; when heterozygous it does not affect females but kills about 15 per cent of the males.

COIL-SPRINGS AND CHROMOSOMES

It has been suggested that in basic structure, chromosomes have the form of coil-springs. Both cytologically and genetically, chromosomes have been shown to require certain mechanical behaviors which are called by such names as crossing-over, deficiency, duplication, non-disjunction, fragmentation, dislocation and reverse order. If, in shape, chromosomes are really coil-springs then certain chromosome-phenomena must tie-up in parallel fashion with the behavior of coil-springs; that is, chromosomes must follow certain analogous mechanical rules which govern coil-springs when, for example, "splitting the strand of the coil lengthwise and separating the resulting coils," or when "crossing-over." The mechanical and mathematical rules which govern coil-springs, when made to present phenomena parallel to those known in chromosomes, have been worked out by Laughlin, and coil-spring models built to show such mathematical and mechanical parallelism in eleven situations.

TRANSMISSION BY INOCULATED CELLS**LEUKEMIA IN MICE**

Up to this point we have considered first the gene, as the ultimate regulator of development in the ancestral way. Next we have considered the chromosomes which constitute the mechanism for transmitting the entire equipment of genes. In another laboratory in this Department we are studying somatic cell mutations. Cytological studies indicate that these mutations are not chromosomal, so that we infer gene changes from the cell behavior. These are the specific changes in lymphoid tissue responsible for the disease lymphatic leukemia. This work is being carried on under the leadership of MacDowell in cooperation with the Department of Pathology of the College of Physicians and Surgeons, with the support of a grant from the Carnegie Corporation.

Critical evidence of the neoplastic nature of leukemia was reported a year ago by MacDowell and Potter in the demonstration that leukemic cells continue to divide indefinitely in a suitable host environment, and in the metabolic work of Victor which shows a similarity between leukemic tissues and recognized neoplasms. This is of importance because in man the high incidence of bacterial infection in leukemia has caused doubt as to its etiology and nature. As Dr. Victor of the Department of Pathology points out, the mouse material is uniquely valuable for bio-chemical studies relating to tissue respiration and fermentation because of the genetic control of cell type, clinical course, pathologic distribution and host resistance. This control, together with considerable increase in accuracy in weight determinations of tissues used, has made possible unusually uniform results. For example, Victor's determinations of oxygen consumption give standard deviations ranging from 3 per cent to 14 per cent of the means as contrasted with 45 per cent (Warburg) and 70 to 80 per cent (Jackson, Parker and Glover).

The determination made this year by Victor, assisted by Miss Margaret Prest, at the College of Physicians and Surgeons, confirmed previous findings that the metabolism of leukemic cells differs from that of normal cells and resembles that of malignant tumors (as reported by Warburg), in the consistently increased anaerobic glycolysis. The ratio of aerobic glycolysis to oxygen consumption rises from a normal of 0.4 to, respectively, 1.0, 1.4 and 0.9 in three transmission lines.

These results agree with the findings for sarcoma of Barron and many other investigators. However, evidence is completely lacking of an impairment in oxydative capacity which is required for Warburg's interpretation of malignancy. Indeed, oxygen consumption was significantly raised in some cases. While other investigators have neglected to use for comparison normal tissues of the same type as the malignant tissue, in this investigation lymph nodes have been used in all determinations. The normal nodes have been compared with nodes taken at a time after inoculation when the infiltration of leukemic cells has become so extensive as to obliterate all the normal architecture and transform the node into a mass of malignant cells. To determine this time, which varies with the line of cells and strain of hosts, Potter made special studies of the progress of infiltration in each of the combinations of lines and strains studied by Victor.

A distinction must be kept clearly in mind in what follows. The term *strain* is applied to the continuum of inbred mice descended from a common ancestor; the term *line* to the continuum of leukemic cells through whatever individual mice they may have been passed.

INFLUENCE OF HOST ON LEUKEMIC CELLS

For some time it has been known that mice of our strains C58 and StoLi differ in susceptibility to leukemic cells of both line I and line M-liv. Strain C58 has always been 100 per cent susceptible to these two lines. Strain StoLi on the other hand was 100 per cent resistant during the early history of these lines. In the year under review, however, the virulence of both lines had increased to the point of growing even in strain StoLi.

At this time Potter made a cytological study day by day of line I cells in strain StoLi comparable to that reported last year in the host strain C58. The size of the predominating cell was measured, and the path and rate of dissemination of the cells after inoculation, as well as the morphological characteristics of the cells, were determined. Potter found that during the first 72 hours after inoculation, the leukemic cells in strain StoLi developed at the same rate and reached a like stage of infiltration as in the hosts of strain C58. After 72 hours, either the infiltration persisted until death of the StoLi host or underwent regressive changes that led to recovery of the hosts. In the first case the interval between inoculation and death of hosts was only slightly longer than in hosts of strain C58. In the second case (recovery) the cells of the line apparently did not differentiate but died and were phagocytized by the host cells.

Victor reports that the normal lymph nodes of mice of these two host strains have the same metabolism and that in the hosts of one of these strains (C58) two lines of cells (I and M-liv) at this period gave the same metabolism. However, infiltrated with cells of line I, nodes of StoLi hosts compared with C58 hosts have higher oxygen consumption, decreased anaerobic glycolysis and irregularly decreased aerobic glycolysis. Infiltrated with line M-liv, nodes of StoLi hosts compared with C58 hosts have the same oxygen consumption and both aerobic and anaerobic glycolysis are very much diminished. These differences in metabolism of lines I and M-liv when grown in StoLi hosts are neither cumulative in continued transfers in StoLi hosts, nor are they indicative of any modification of the cells themselves, since in returning to hosts of C58 they show at once the same metabolism as cells of these lines grown throughout in C58 hosts.

Thus lines of cells that have the same metabolism under one set of conditions may have quite different responses to a change in these conditions. And further, different strains of uninoculated mice may show no metabolic difference, but infiltrations with the same line of leukemic cells may develop metabolic differences which depend upon the genetic constitution of the host. Such differences between hosts are related to the genetically controlled susceptibility to particular lines of leukemic cells, which susceptibility is, accordingly, not related to host metabolism. The metabolism of leukemic cells is not an absolute but an interaction between the constitution of the cell and the constitution of the host.

**METABOLIC AND CYTOLOGICAL DIFFERENCES BETWEEN CELL-LINES
OF LEUKEMIA**

Studies are being made of various lines of inoculated leukemia to distinguish between specific secondary line differences and the essential features of malignancy; to develop fundamental relationships between physiological and morphological traits of cells and to approach the problem of the spontaneous occurrence of leukemia. The individuality of the different inoculation lines from different spontaneous cases has now become so impressive as to lead toward the conclusion that each case of spontaneous leukemia has its own individuality even though originating in the same genetically homogeneous strain of mice. As MacDowell points out, such differences correspond to the individuality that appears in other forms of cancer and has produced conflicting findings. Thus, on the single criterion of size, leukemic cells fall into a graded series from small to large. Clearly various types of lymphocytes carry malignancy.

The twelve lines of leukemic cells that Potter has now studied cytologically differ not only in the size of the predominating cell type but also in virulence (time required for massive dose to kill host), distribution and type of lesion, cultural requirements in host, nucleo-cytoplasmic ratio, distribution of chromatin, rate of cell division, rate of dissemination of cells, number and form of mitochondria, frequency distribution of cell size within a transfer, oxygen consumption, aerobic and anaerobic glycolysis.

Frequency distributions of cell size give a more complete picture of leukemic differentiation than does the average size of the predominating cell type. All measurable cells (800 per determination) in fields of maximum infiltration are classified into four size groups and reduced to a percentage basis.

The three criteria of line differences in metabolism have been established this year by Victor, working with lines A, I, M-liv and MsplD, all in hosts of strain C58. The accompanying table shows the diversity between the four cell lines. Two of the lines differ significantly from normal in oxygen consumption, three in aerobic glycolysis and all four in anaerobic glycolysis. But each cell line shows a characteristic deviation from normal anaerobic glycolysis, *i.e.* 2.5, 7.0, 14.0, 9.5 units.

Cells	Oxygen consumption			Aerobic glycolysis			Anaerobic glycolysis		
	Mean	Diff. from normal		Mean	Diff. from normal		Mean	Diff. from normal	
Normal.....	5.45	.....	.....	2.13	.....	.....	5.78	.....	.....
Line A.....	6.40	0.95±	0.15	1.88	-0.25±	0.14	8.31	2.53±	0.44
I.....	5.47	.02±	.12	5.57	+3.44±	.62	12.76	6.98±	.57
M-liv.....	5.78	.33±	.23	8.40	+6.27±	.31	19.78	14.00±	.47
MsplD.....	6.68	1.23±	.19	6.15	+4.02±	.18	15.31	9.53±	.38

CHANGES IN CELL LINES

The preceding list of criteria offers a close check on the occurrence of changes in cell lines. Last year changes in virulence were reported; this

year changes in gross lesions, cell traits and metabolism have been observed. Knowledge of the nature and structural basis of these changes may be expected to throw light on the problem of the changes which transform a normal cell into a leukemic cell.

A series of eight sublines from one spontaneous case was started in January 1932 and carried on by the most uniform technique that could be devised from our previous experience. In all cases virulence increased during the course of transfer: (1) rapidly and continuously during the early transfers; (2) very slowly and continuously over many transfers after stabilization of the line; (3) abruptly, within one or two transfers, at any time. What is the inter-relation between these different types of change in virulence? Are they different manifestations of the same process? How are they related to changes of lymphocytes from normal to malignant?

Starting with the most abrupt change in virulence, the frequency distributions of cell size in the successive transfers were obtained. These showed a marked increase in the proportion of the next to largest cell class, which began gradually a few transfers before the sudden change in virulence and increased rapidly at the time of the sudden change. Thus a relationship was established between the shift in population of cells and the change in virulence of such a nature as to indicate a dependence, above certain thresholds, of virulence upon cell type. Similar studies on other periods of sudden change confirm this conclusion. Furthermore, the specific positive correlation of virulence and cell size indicated by comparison of different lines and by comparison of spontaneous cases and early transfers with late transfers is strikingly confirmed.

Since abrupt changes are unpredictable, Victor has made a metabolic study of each of the first eight transfers of a new line, during which continuous changes in virulence occurred as expected. None of the three criteria of metabolism showed changes that could indicate a casual connection with the changes in virulence, although anaerobic glycolysis showed a very slight though continuous rise. Further indication of the weakness of the relation between virulence and metabolism is given by a distinct metabolic difference between two lines of cells (I and M-liv) at a time when their virulence and morphological traits (except mitochondria) were alike. In spite of all this there does stand out a general tendency for the more virulent lines to show higher glycolysis.

A close correlation appears between aerobic glycolysis and the character of certain cell granules (called mitochondria) lying outside the nucleus. Their number and shape have been studied by Potter and Miss Findley in the lines whose metabolism was studied by Victor. At the same time lines I and M-liv were found to differ in metabolism, the mitochondria were the only other criterion that showed a difference. Further, the metabolic differences that each of these lines showed when growing in hosts of strain StoLi were accompanied by changes in the number of mitochondria within each line. That mitochondria are related to carbohydrate metabolism has long been suspected, but hitherto not clearly demonstrated.

The interpretation of changes in cell lines that has seemed most plausible is that the process of transfer acts as a constant selective mechanism work-

ing toward greater adaptation. That different lines of cells proliferate more extensively in some organs than in others suggested that within a spontaneous case leukemic cells from one organ might be genetically different from those in some other organ. A test of such diversity of cells was attempted by using cells from different tissues of the same spontaneous case as the start for different transmission lines, to be carried by successive transfers of the same type of tissue originally used. The early transfers in all lines gave remarkably similar results, but differences shortly appeared in distribution of lesions, metabolism and in cell morphology. In no case was there any indication that the cells taken from different parts of the spontaneous case had any special relation to the type of tissue used, nor was such a relationship developed during the course of transfers. Frequent control transfers with cells from spleen checked this conclusion. Although variations of leukemic cells according to the part of the body were not found, the interpretation that the changes observed are dependent upon a selective action working on a mixed population of cells still stands. It receives support from cytological studies indicating that differential rates of cell division at periods of rapid change are associated with changes in composition of populations of leukemic cells.

ORGAN-SECRETIONS AS AGENTS IN GENETICS AND DEVELOPMENT

The leading work in this field of genetics has been done, in this Department, by Riddle and his associates, Bates, Cauthen, Dykshorn and Lahr. Researches have been made primarily on the pituitary gland and secondarily on the thyroid and germ glands.

A THIRD HORMONE OF THE ANTERIOR PITUITARY GLAND

Last year was reported the isolation of a hormone from the pituitary gland that provides the immediate stimulus to milk secretion in mammals and to crop-gland development in pigeons. During the present year efforts have been concentrated upon an extension of our knowledge of this and other anterior pituitary hormones. In the period under consideration there appeared the full publication of Riddle, Bates and Dykshorn. Their results were summarized as follows:

"A new anterior pituitary hormone, called prolactin, was shown to be neither prolactin nor the growth nor the gonad (and thyroid) stimulating hormone of the anterior hypophysis. It caused (a) secretion of milk from the prepared mammary glands of normal and castrate guinea-pigs of both sexes, of normal and castrate female rabbits, of hypophysectomized rats, and of normal and castrate female monkeys; (b) growth with secretion in the crop-glands of doves and pigeons of both sexes, including one without hypophysis and 5 castrates.

"Prolactin was prepared by alkaline (also acid) extraction of bovine or sheep anterior lobes, removal of an inert precipitate at pH 7.5-8.0, followed by precipitation and washing of the prolactin fraction at pH 5.0. Prolactin so prepared gives no stimulation of the immature bird testis. Various treatments cited by others as destroying the growth hormone did not destroy prolactin.

"The fraction soluble at pH 5.0 contained the gonad-stimulating (sex-maturity) hormone. When either this latter fraction, the 'aqueous pyridine and water-soluble' fraction of Fevold, *et al.*, the thyreotropic fraction of Collip, or commercial antuitrin was injected, the testes of immature doves were enlarged 3 to 10 times within 4 to 10 days with little or no enlargement of the crop-glands. Prolan (antuitrin S, and fresh preparations) had no effect upon either gonads or crop-glands of doves or pigeons.

"Growth hormone preparations of Lee and Schaffer, Collip, and Van Dyke gave only traces of crop-gland stimulation and very rarely a lactation response. An Evans growth preparation and antuitrin G strongly stimulated the crop-gland. All growth preparations tested, except that of Collip, Selye and Thomson, strongly stimulated the testis of the immature dove.

"Numerous tests proved that pure gonad-stimulating and growth hormone stimulated neither the crop-gland nor lactation; and other tests demonstrated that these two responses are induced by the same hormone—prolactin.

"Prolactin induced secretion of milk beginning about the fourth day in guinea-pigs and after 2 to 3 days in rabbits. Daily injections of prolactin into doves or pigeons increased the weight of the crop-glands up to 7 days, when the maximum was attained.

"Prolactin at pH 7.5 to 8.5 heated for one hour at 100° C. showed little loss of potency. Sodium chloride increased the rate of destruction."

It seems probable that non-physiological or pathological effects or responses which are not specific to any anterior pituitary hormone are induced by the simultaneous administration of two or more potent principles which never normally coexist in such high concentration in the blood. Thus Riddle had noted some years ago that marked enlargement of the liver regularly results from the injection of impure pituitary extracts into doves and pigeons. The same phenomenon, and also glycosuria, has been observed in mammals also. The studies of this year have supplied evidence that this response is an induced pathological state. This combined effect calls for further and serious study. It is hoped that the work on prolactin will be of aid in the general, formidable task of purifying and determining the interactions of the various anterior pituitary hormones.

During the year a method for the quantitative assay of prolactin, based upon crop-gland response, has been developed by Bates. It has been found that as little as 0.2 of a milligram of our present preparations gives a positive biological test. For some months much time has been spent in isolating and assaying on animals the considerable amounts of prolactin currently used in clinical tests of this hormone. Such tests, made by others, have shown the effectiveness and usefulness of this hormone in medicine. In this practical application the stability of the hormone is of importance and this feature has been studied by Bates.

Incidentally, it has been found that prolactin exerts a depressant action on the adult testis of birds and it is possible that it will be found to be connected with—and serve well to clarify—the process of "luteinization" in the ovaries of mammals.

AN ANTERIOR PITUITARY HORMONE THAT STIMULATES THE THYROID GLAND

It is known that one or another of the hormones produced by the anterior pituitary gland is essential to the normal functioning of the thyroid gland, and that when this hormone is supplied in excessive amount the thyroid enlarges and increases the rate of heat production in the body. We have studied the capacity of the different anterior pituitary hormones (or extracts) to effect those two thyroid responses in ring doves.

In the study on thyroid enlargement it was found that usually, but perhaps not always, those pituitary extracts which cause growth in the gonads also cause enlargement of the thyroids. Further, that neither the growth hormone nor prolactin has any specific capacity to produce this hyperplasia of the thyroid. A publication on this subject by Riddle, Bates and Dykshorn was summarized as follows:

"For the first time it is shown that two anterior pituitary hormones—prolactin and the growth principle—do not cause the thyroid hypertrophy which characteristically follows the injection of various pituitary extracts. Hyperplasia of the normally developed thyroid following pituitary administration is a specific response to the gonad-stimulating hormone, or to another pituitary derivative having very similar solubilities. Good gonad-stimulating preparations do not invariably induce an increase in thyroid weight in doves and pigeons."

A parallel study of the effects of the various anterior pituitary hormones on the rate of heat production (basal metabolism) is now under way, with the aid of Dr. Bates, Mrs. Smith and Mr. Lahr. This aspect of the pituitary problem assumes further importance because Dr. P. E. Smith, of Columbia University, has supplied evidence that there are two anterior lobe hormones which affect thyroid activity—one accelerating and one depressing it.

ACTION OF PITUITARY HORMONES AND PROLAN ON MATURE GERM GLANDS

Riddle, Bates and Lahr have made three contributions to this subject. First, prolactin seems to have a specific inhibiting or depressant action on the mature testes of doves and pigeons. This effect of the prolactin perhaps explains the lack of desire of the male bird to copulate during incubation, for evidence has been found that the secretion of prolactin—which is to result in crop-milk formation at the end of the brooding cycle—really begins as soon as the parent birds begin to incubate the eggs.

Second, the injection of good extracts of the gonad-stimulating hormone into adult males results in increased weight of the normal testis and has a powerful stimulating effect on the adult ovaries of doves and pigeons. At the same time body weight is reduced. This weight reduction is considered a secondary action of the hormone, since it causes increased activity of the thyroid, hence an increase of metabolism and a tendency toward emaciation.

Third, prolan—obtained from the urine of pregnant women—is believed by some to be a mixture of two substances, both derived from the anterior pituitary; one is believed to promote true gonadal growth while the other induces "luteinization" of the ovaries. By the use of available samples of prolan and other preparations of our own we find a slightly adverse effect

upon the adult testis of doves and pigeons. Prolan has, however, no capacity to enlarge the thyroids in our animals; and, wholly unlike prolactin, which markedly represses the testis, it has no capacity to stimulate the crop-glands nor to induce lactation. Our results give little or no support to the conclusion that the "luteinizing substance" obtained from pregnant urine is a pituitary derivative.

BASAL METABOLISM OF DOVES AND PIGEONS

Riddle's studies on basal metabolism, done in collaboration with Dr. F. G. Benedict, director of the Nutrition Laboratory, and with the assistance of Mrs. Guinevere C. Smith, are largely concerned with a variation that is associated with race, sex, hybridity and reproductive stage. This year studies have been made upon variation in metabolism associated with age and the free-flying state. Riddle's study of effect of advanced age supplements certain work that Dr. Benedict is doing on man and rat. Studies on adolescent pigeons (tipplers) will be valuable for comparison with results obtained from birds in which ovulation has already set in. In the free-flying studies, Homer pigeons are used, which have been carried to varying distances from the laboratory so as to force them to undertake prolonged flights.

The reproductive cycle in doves and pigeons involves a cycle of marked changes in behavior, endocrine status and body weight. Of these "broodiness," in which the male takes full part, is one of the most striking. Riddle, Smith and Benedict have concluded a study of the changes in metabolism of ring doves after they have been incubating eggs during 10 to 14 days. Though evidence was found that this period of unusual inactivity is accompanied by a 10 per cent decrease in the metabolism of males, no change was found in that of the female. But this result was obtained only when the birds were measured at an environmental temperature of 20° C. When measurements were made at 30° C.—the so-called "zone of thermal neutrality"—irreconcilable results were obtained. Since other evidence indicates the validity of the results obtained at 20°, the validity may be questioned, at least for birds, of measurements made as in current practice, at the zone of thermal neutrality, when the object of the measurement is to disclose the influence of one or another factor on the current basal metabolism.

Again, Riddle with the assistance of Miss Pela Braucher, having found that his birds gained weight during the incubation period, and having formulated the hypothesis that this result is associated with a decrease in the basal metabolism of the incubating pair, is now undertaking, with Mr. Cauthen and Mrs. Smith, a general study of the relative rates of food consumption during the various stages of the reproductive cycle.

HISTOLOGICAL CHANGES IN THE OTHER ENDOCRINE GLANDS RUNNING PARALLEL TO THOSE OF THE ANTERIOR PITUITARY GLAND

In this important part of our program Dr. Riddle is being assisted by Mr. Lahr, who has sectioned and studied a very large number of ovaries, testes, mammaries, etc.

A PROTOZOAN DISEASE IN PIGEONS

Our ability to satisfactorily carry out genetical endocrine studies on doves and pigeons depends upon the health of the stock. Many deaths occur, due to a parasitic worm that inhabits the alimentary tract and which belongs to the genus *Capillaria*. With the aid of Mr. Cauthen this parasite has been brought under control. But a Protozoan, *Trichomonas columbæ*, that lives in the upper alimentary tract and forms fatal cysts there and even gets into the liver, pancreas, lung and heart, has been the subject of special attention but has not yet been brought under control.

TRANSMISSION BY SEX CELLS

GENETICS OF CLADOCERA

Banta, who has been associated with us during summers, has continued his researches on the genetics of Cladocera. Continued studies of dwarf strains demonstrate that dwarfness is due to slow rate of growth and development, perhaps governed by a single recessive factor which, in addition to what is apparently another single recessive factor, causes a cessation of pre-adult growth and the onset of reproduction while the animals are still below normal adult size.

ACCUMULATION OF RECESSIVE MUTATIONS DURING LONG-CONTINUED PARTHENOGENESIS

This process, which has been abundantly and strikingly demonstrated in *Daphnia longispina*, has been worked out in other species of Cladocera by Miss Thelma R. Wood and Mr. George A. Smith. They inbred (by sexual reproduction, of course) *Moina macrocopa* which had passed through 1090 generations of parthenogenesis and compared the resulting recombinants (sexually produced offspring) with parthenogenetically produced offspring from the mother alone. There was more sterility, greater variability in reproductive capacity, in longevity and in other physiological characteristics among the recombinants than among simultaneously reared clonal sisters. Apparently recessive mutations similar to those detected in *D. longispina* occur in *M. macrocopa* also.

THE HATCHING OF SEXUAL EGGS OF CLADOCERA

As previously reported, Miss Wood found that a considerable portion of winter eggs of *Moina macrocopa* hatch without a latent period. Since these would frequently hatch when conditions were not just right for survival, it seems that they would be selected against. Now, Miss Wood has found that many of the eggs of *Daphnia longispina* also will hatch a week or so after being laid and without having been dried. Viability of the sexual eggs, as revealed by their hatchability, is decreased by dry storage prolonged for a period exceeding 3 or 4 months and becomes very low after 9 to 12 months. Storage in water without disturbance or renewal of evaporated water is less deleterious.

DEVELOPMENTAL NORMS FOR DAPHNIA

As a useful step in genetical studies, Miss Wood has been making determinations of developmental norms for *Daphnia*. Sizes are determined at different instars. It appears that body length at time of birth is about

0.65 mm., at the 6th instar (after the first young are produced) is about 1.72 mm. This increase is made during 120 hours. In terms of the first instar the ratios of the first six instars are, respectively, about 1, 1.23, 1.59, 2.03, 2.43 and 2.66. There is a progressive diminution in percentage increment of these ratios; while the duration of the instars increases progressively in the proportions of 1, 1.01, 1.14, 1.44 and 2.33. It has been discovered that instead of the usual 4 instars before adulthood is reached there may be 5 and occasionally as many as 7. More rarely there are only 3.

STUDIES ON EFFECTS OF CONCENTRATION OF MEDIUM AND NUMBER OF ANIMALS ON RATE OF DEVELOPMENT

Under Banta's direction, Miss Maurita McPherson some time ago made experiments designed to test Robertson's allelocatalytic theory of growth, which grew out of Robertson's discovery that several unicellular organisms in a drop will reproduce faster than only one. Miss McPherson found that by varying (1) the concentration of the culture medium and (2) using differing numbers in equal amounts of culture medium, she could govern the rate of development of *Moina macrocopa*. With series consisting of 1, 3, 6 and 9 animals in the same concentration (and same amounts) of culture medium the single animals developed more quickly than the plurals when the medium had less than optimum concentration; but when the concentration was above optimum the groups of animals developed more rapidly than the single ones. This study has been extended by Mr. George A. Smith, using (like Robertson) a Protozoan, *Paramecium caudatum*, and by various methods he has found results very similar to those from *Moina*. Single *Paramecia* in weaker media have, in general, a greater fission rate than plurals; in concentrated medium plural animals have a higher fission rate than singles. It may be concluded then that Robertson and his supporters probably utilized culture media stronger than optimum for a single animal and consequently his plural animals reproduced more rapidly than singles. On the other hand those investigators who failed to confirm Robertson's results may readily have used a less concentrated medium which permitted the isolated animals to have as rapid as, or a more rapid rate of fission than, plural animals in the same amounts of the same medium. That is, it is possible to obtain results (1) similar to those of Robertson, or (2) similar to those obtained by Robertson's opponents by varying the experimental set-ups.

GENETICS OF THE THOROUGHBRED HORSE

After years of intensive compilation and analysis of data on the racing capacity of the running horse, made possible largely through the monetary contributions of Mr. W. J. Salmon, Laughlin is now engaged in working up his findings for publication.

THE MEASUREMENT OF RACING CAPACITY

A necessary preliminary to the study of inheritance of racing capacity is the quantitative expression of that capacity. Laughlin has devoted much time to the devising of an appropriate "yard stick" for this purpose. This he has successfully accomplished. The formula for measuring the racing

capacity of the individual horse depends upon the measure of quality of performance in each of his several races. In turn the formula for the quality of performance is a mathematical expression in which the speed-performance of the particular horse in the particular race is a function, simultaneously, of sex, age, weight-carried and distance-run, other factors being constant. Separate formulas have been computed for colts, geldings and fillies. The formula for colts together with a set of mathematical models of the formula are given in the accompanying figure.

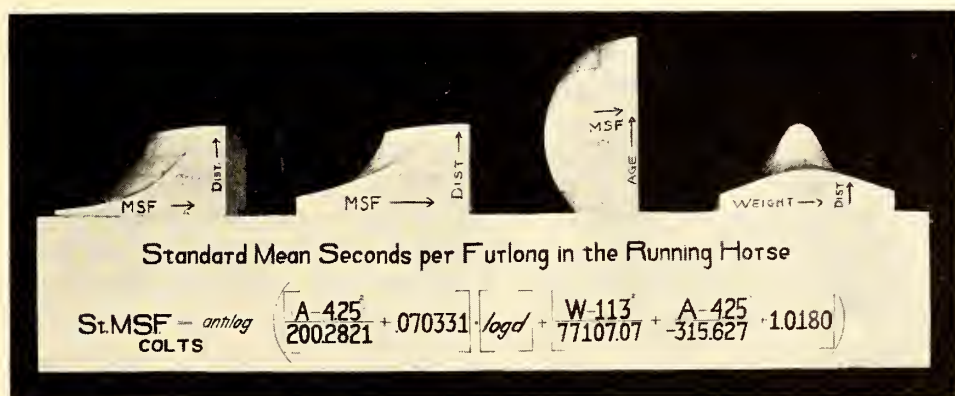


FIG. 2—Formula for standard means seconds per furlong in colts and a set of mathematical models of the formula.

In the formula, St.MSF stands for Standard Mean Seconds per Furlong, that is, for the mathematically smoothed best record which American "horse-flesh" has achieved for the particular complex of sex, age, weight-carried and distance-run. In this formula "A" stands for age in years, "D" for distance-run, "W" for weight in pounds carried on the back. How good a horse is, that is, the measure of his racing capacity, depends upon how nearly, in his several races, he approaches the St.MSF for the same set of conditions. For example, for colts 3.75 years old, the left-hand model shows, on the front face, the relation between the number of seconds required by the "standard colt" to go a furlong and the distance run in the race. It shows that the longer the race the slower the rate (more seconds per furlong). Sections cut parallel to the front face vary in form with increasing weight-carried. Thus, "seconds per furlong" diminishes as weight-carried increases to a certain point and, thereafter, speed is retarded.

Practical work tables have been completed for the values of these formulas for every practical complex of these several constituent factors. As working material the racing-capacity measures have been worked out for a few more than 10,000 of the best Thoroughbred horses in England, United States, France and a few other countries.

INHERITANCE OF RACING CAPACITY

Laughlin has made further analysis of this topic, has worked out an "operative formula" and has made a mathematical model for the formula; of which the three dimensions are: (1) the futurity index (or the prediction

basis); (2) the thing predicted (or offspring-racing-capacity within a 5-pound range); and (3) the vertical coordinate, or probability. Thus, if a foal is born with a futurity index, or hereditary promise, of 120.39 the probability of racing-capacity-range for this foal, if it is raised to maturity and races under average American conditions, is 0.121 for the class 110 to 115; and 0.104 for the class 115 to 120. In higher and lower racing-capacity classes the probability becomes smaller and smaller, until at 60 to 65 the probability is 0.013, and at 130 to 135 it is 0.012, the total probability by capacity-class for the same prediction-basis being 1.000.

Laughlin emphasizes the point that he has still to continue the search for the genetic elements ("specific stresses") for each of the near antecedent bloodkin, which, entering into the prediction index, will give the best prediction. He calls attention to the fact that racing capacity, far from being based upon a single Mendelian unit, or upon the additive and segregable resultant of a few such units, is the developmental end product of the interaction—accelerative, cancellative, creative, additive—of a host of Mendelian units—perhaps hundreds. Still the end-product, racing capacity, is a thing which is definitely measurable in the individual and which definitely runs-in-the-family.

THE GENERAL FORMULA OF HEREDITY

As an outgrowth of the operative formula for the inheritance of racing capacity in the Thoroughbred horse, Laughlin has worked out a general formula of heredity. This gives the probability (K) that a random-selected offspring with a given prediction-basis (M) (derived from the quality in antecedent near-kin) shall fall within (R) the selected class-range of offspring. Since many complex traits are not analyzable or predictable in terms of definitely numbered genes, he believes that this general formula will be useful in many physical and medical investigations. It may be generalized as $K=f(M, R)$. In actual use for specific formula-finding, it is demonstrated that the correct numerical values for each of eleven constants will suffice to fit quite closely the general formula to any extensive group of accurately observed inheritance-data.

THE MEASURE OF EVOLUTION

Laughlin concludes that the foregoing general formula of heredity is available for analyzing problems in evolution; particularly it may be used (a) to predict evolution in a very slight character-change from one generation to another, (b) to determine the trend or direction of evolution, (c) to locate its current goal or (better) its target, (d) to mark its progress, per generation, toward its present target, and (e) to describe the constitutional nature of the population of which the particular sample is truly representative. Laughlin points out that the measure of evolution consists not in comparing the mean of the parental group with the mean of their offspring, but the mean of the parental group with the point of no regression.

Instead of assuming the mean of the breed, the mean of the parents and the mean of the offspring to be the same, it is found more useful to plot the prediction diagonal, *i.e.*, the line which connects points of equal value for parents and for offspring, and then to plot against this line for each

parental prediction class the mean of the offspring of that class. Through the series of points marking such means of offspring-classes a curve is then fitted and the point computed at which the prediction diagonal and the smoothed curve of the offspring-class centers cross. This crossing point is the point of no regression; it is the point of the true genetic mean; the point toward which the breed, represented by its particular sample of breeding-stock, actually tends to move from the particular parental generation to the immediate offspring of that generation. If, for example, only a highly selected sample, say "the cream of the breed," is dealt with, the general formula detects a genetic mean; whereas without the technique of this formula the actual point of no biological regression, being outside the mean of immediate consideration, would be difficult to locate.

The foregoing principles are illustrated by the data obtained from a group of 54 Thoroughbred foals produced during the years 1924 to 1928 and raced between 1926 to 1931. The mean hereditary promise, or futurity index, of these 54 foals was 116.08, while the mean racing capacity was 97.76. These data are substantially above the point of no regression. Using them in the way described, it is found that the genetic mean of this particular sample of Thoroughbred racing stock is located geometrically at 64.38. This analysis shows why highly selected breeding stock of any breed must be subjected continuously to the most radical selection if extreme standards are to be kept up. The "cream of the breed" regardless of their individual quality, unless their genetic mean can be kept up, constitutes a highly artificial "individual-selection-group," and not a subspecies or a superior strain. This finding is in general keeping with the experience of breeders who strive for highly specialized and extreme values of any type.

On the other hand, random-selected good stock, but below the genetic mean, if given fair opportunity, will, like their superiors, tend to gravitate toward the genetic mean, but this time such gravitation is an improvement rather than a loss. Thus the genetic mean is not to be confused with the somatic mean of parents and offspring.

In further application of the general formula of heredity, Laughlin makes use of the data of Galton's study on inheritance of stature in British families. The mean stature of the 928 children (commuted to the male basis) is 68.09 inches, and the average mid-parental stature is 68.66 inches. The genetic mean derived from these data is 68.54 inches. Thus it appears that in the families measured by Galton not only were the mid-parents taller than the children by something more than a half inch, but the genetic mean of the particular breeding-stock was not quite so great as the mean of the breeding-stock itself. It is logical to conclude that for this particular sample of breeding-stock for this particular generation the stature was degenerating about one eighth of an inch.

On the other hand a similar analysis of a large number of American children and parents indicate a genetic mean at around 74 inches for men and 69 for women, so that if this particular sample be considered as a segregated population of breeding-stock, the two generations studied show a decided evolutionary trend toward substantially taller stature.

Laughlin also applies his general method of determining the genetic mean to Osborn's studies on skull-length in Titanotheres. During approxi-

mately 15 million years this skull-length had increased from 31.3 centimeters to 80.0 centimeters. Laughlin concludes that from generation to generation Titanotheres skull-length was moving toward a genetic mean of 120 to 130 centimeters—a giantism probably far beyond the physiologically fatal limit. At the earlier rate, this attainment of this extreme skull-length would have required 20 or 30 million years more. The genetic constitution which moved successive offspring toward such a goal may have been one of the major causes for the disappearance of the Titanotheres.

Laughlin suggests that his mathematical considerations lead to the conclusion that evolution is the resultant of the interaction of the genetic constitution on the selective forces, internal and external, which operate during the turn-over of individuals from one generation to another. Considered as a breeding movement, evolution is the trend of the somatic mean toward the genetic mean; the internal immediate or driving force of evolution is the difference between these two means.

HUMAN GENETICS

RACIAL DIFFERENCE BETWEEN INDIANS, NEGROES AND DUTCH

This study is being developed by Steggerda along the lines laid down in last year's report. On August 25th he and Mrs. Steggerda started for the Southwest and made their headquarters at Santa Fe, New Mexico. They worked at the following schools: Rehoboth, Crown Point, Fort Defiance, Ganado, Tuba City. At these points on the Navaho Indian Reservation a total of 382 children was measured. Considerable time was spent in securing birth records of the children, and it is probable that much of the data can not be used because of incompleteness in this essential item. This work is largely preliminary; the genetical, familial studies will develop later.

The month of November was spent in Holland, Michigan, continuing the genetical growth studies on children of Dutch descent. The number of children in the growing series now measured twice is 232.

On January 17, 1933, Dr. and Mrs. Steggerda left for Yucatan, for the third year of study of the genetics and growth of the Maya. At present there are 92 boys and 78 girls whose development is being traced, at the villages of Pisté, Chan Kom and Xocempich. March and early April were spent in a reconnoitering trip in Guatemala and Southern Mexico. A number of Indians were measured at the principal stopping places on this trip.

During the latter part of April and part of May, a series of measurements of growing children was begun at Tuskegee Institute and vicinity. This study was facilitated by the cooperation of the principal, R. R. Moton, LL.D., and Mrs. Louise M. Atkins of the faculty. The series comprises about 108 children, whom it is proposed to measure in successive years.

SPECIAL STUDIES AT YUCATAN

The difficulty of determining the age of children in a country where birth records are not scrupulously kept is considerable. There are, of course, some records. Then, as family pedigrees are worked out and each pregnancy becomes accounted for, the age of each child can often be estimated fairly closely. The time of starting to attend school helps. Physiological age of

girls can be known with precision, since it is the custom for girls to cease going to school at the first day of the onset of the menses. For boys the development of terminal hairs will aid in determining physiological age. Incidentally, it may be mentioned that marriage of girls takes place frequently within a year or two after puberty sets in, and they become mothers at 15, 16 and 17 years. Infantile deaths are very common, even where the mother is quite matured.

The necessity of knowing intimately the family has led Steggerda to make a census of the entire little village of Pisté. This village is the nearest settlement to the excavations being made at Chichen Itzá. Most of the workers at these excavations come from Pisté and as they receive silver for their labors the village is one of the wealthiest of its size in the peninsula. In about 80 houses there was a total of 153 adults and 150 children. There was a record of 87 children who had died. The corn, which constitutes perhaps the principal article of diet of the inhabitants, is grown on some 6000 mecatés, or something less than 600 acres. There were 65 horses available for the 85 men. In addition there were 46 cows, 262 pigs, nearly 1000 chickens, and 100 dogs (mostly used for hunting). A few goats and bees constitute the remainder of the domestic animals.

The size of the village depends in part upon the capacity of the soil to feed the population. It is well known that a corn field, or milpa, is planted in Yucatan for two successive years only, on account of rapid loss in yield. Seeking the reason for this loss in yield (which may be a factor in the desertion of ancient Maya cities), Steggerda has collected samples of soil from a new milpa and also one in its second year. These were analyzed for us by the Division of Soil Fertility, U. S. Department of Agriculture, in Washington (Oswald Schreiner, Chief) and a report made showing a marked loss of nitrogen and other organic constituents in the soil. The report concludes:

"The analyses of the two samples, submitted from new and old milpas, would seem to indicate that the differences are due to oxidation of the organic matter owing to high temperature and aeration. The exchangeable bases, especially the calcium, which were previously held, could then be leached rapidly by the presumably high rainfall. It seems entirely improbable that the relative exhaustion indicated by the analyses is due to the direct removal by a few years of cropping."

DENTAL STUDIES

At the request of Dr. Weston A. Price of Cleveland, Ohio, Steggerda gathered 30 small vials of saliva from 30 Pisté men. It is hoped that these will be a contribution toward an explanation for the excellent teeth of the rural Maya. A comparison of the full-blooded Indians of the Chichen Itzá region with Jamaica Negroes on one hand and Smith College students on the other indicates that the teeth of the Maya are comparatively resistant. This is opposed to the conclusions of Dr. Williams.

COMPARISON OF STATURE OF CARVINGS WITH STATURE OF LIVING MAYAS

Steggerda was interested to see whether the carved human figures on the colonnade in front of the Temple of the Warriors are full-size delineations

of the Maya inhabitants of that time. Statures were obtained from 197 carvings, showing a mean of about 121 centimeters and a range between the shortest and the tallest of 25 centimeters. This range is the same as is found upon the living men, but the stature is about 34 centimeters (10 inches) less than the average of present Maya men (155 centimeters). Steggerda believes the purer the blood of the Maya the smaller their stature. He does not, however, feel justified in concluding that the carvings really represent full-size warriors of the day when these carvings were made.

COMPARATIVE STUDIES ON PAPILLARY PATTERNS

Steggerda has been associated with Dr. Harold Cummins of Tulane University in a study of interracial differences in the patterns of the balls of the fingers (finger prints). By grading arches 0, loops 1, and whorls 2 the total value of the finger patterns of the individual ranges from 0 to 20. The higher the value, the more whorls in evidence. Racial comparison shows that the Eskimos lead in the number of whorls, with Indians, Jews, European-Americans and Dutch in descending frequency. Pattern size and pattern form also are quantitatively expressed and racial comparisons made.

COMPARATIVE HUMAN AUXOLOGY

The studies in child development at Letchworth Village have been continued with the hearty cooperation of Dr. C. S. Little and Dr. Eugene W. Martz. All individuals of the series have been seen at six-months intervals. All measurements made on the 40 or more individuals, who have been repeatedly measured for six or more years, have been plotted so as to reveal the course of physical development. Two studies have been published.

Growth of the Human Foot—The length of the foot has a growth that is more or less parallel with that of the body, except that during childhood it may grow faster for a period than the height of the body as a whole. The length of the foot is about 15 per cent of stature in the adult, slightly more in men, less in women. In boys the ratio tends to increase until pre-adolescence, when it reaches a maximum of about 16 per cent, then it decreases. Thus, the foot length tends to anticipate the adolescent spurt. The foot length in relation to lower leg is greatest in the negroes and least in the Mongoloid Dwarfs. The foot length is about 66 per cent of the lower leg length in the adult male. In infancy the foot is relatively much longer (80 per cent, or more of the lower leg) and falls steadily until the adult proportions are reached. The relatively long foot is an anthropoid condition, suitable for grasping limbs of trees, but not for swift running or walking.

The area of the foot grows steadily with age, but rather more rapidly from 8 to 10 years than from 10 to 11. As the adolescent spurt starts in, growth in the foot area becomes faster again and slows up as the adult stage is reached. The foot area of the Negro boys is markedly larger than that of the Nordics. In relation to stature, the foot area increases regularly from 6 to 16 years; that is to say, it is more closely related to the cubic stature, or weight, than to mere height. The area of the foot, age being held constant, has a correlation of about 0.66 with stature and with weight, and the correlation between area of foot and hand, at a particular age, is about 0.67. As the boy

grows the heel elongates more rapidly than the foot as a whole, and assumes a constantly larger angle with the ground, thus increasing the height of the instep.

The mutations that have lead to the human foot are the end of a series of mutations that have been going on for a long time in the Primate series and have been found advantageous for survival. The human foot has permitted the upright position and preserved the hands and the brain for higher functions.

The Crural Index—The crural index is the ratio of the length of the lower leg to that of the thigh, the latter taken as 100. The crural index tends to increase during fetal life and, indeed, into childhood. From an index of about 75, in the first half of fetal life, it rises to around 90 at about 11 or 12 years and then falls to about 86 in adult whites. Thus the change in ratio results from the slower growth of the thigh, as compared with the lower leg, during the period of increase of the crural index; followed by a slowing up of the tibia and more rapid growth of the femur. Relative to the leg as a whole the thigh first decreases, then increases and vice versa in the lower leg. One may say that the tibia grows faster than the femur in early post-fetal life in accordance with the prevailing longer tibia in quadrupedal mammals. In humans, as in the lower Primates, the femur is the larger at the start, showing the precocity of a larger organ and one nearer the trunk. Thereafter the tibia tends to assert itself to assume its role as approximately equivalent to the femur in locomotion; the role that it plays in most mammals, including the lower Primates. Finally, during adolescence, the relatively long femur begins to show itself and the crural index diminishes. The high index is associated with leaping and romping, while the small index is associated more with rapid walking and running. Lamarck's view that function has determined structure receives no evidence from modern genetics; rather the changes in the form of the leg precede and determine how the leg shall be used. The mutation comes first, and function accords with it.

Growth Standards—With the aid of Miss Lillian B. Frink an attempt has been made to secure anthropometric and other observational data upon the parents, brothers and sisters, uncles and aunts, and first cousins of the children who are being followed at Letchworth Village. More or less complete data have been obtained about 110 families.

In order to be able to compare with children between the ages of 6 to 18, the physical proportions of their grown parents and brothers and sisters, of varied ages, it became necessary to establish standards for the different dimensions and proportions for both sexes at all ages, from birth to maturity. The desired standard could not be obtained from the literature on the subject, inasmuch as the results of such detailed measuring have nowhere been published. Using then our own data, we have prepared such standards. The comparison with the standard has to be made somewhat indirectly, namely, by expressing the deviation from the standard in terms of the so-called "standard deviation." Treated in this way, marked deviations from the standard show themselves frequently as family characteristics.

This method rests upon the assumption that the proportions of the individual make their appearance at an early stage of development, that one

may expect a somewhat similar deviation from its standard of a girl of five years and her father of thirty-five years. Preliminary examination of the subject shows that there is some warrant for this expectation, though of course it does not hold rigidly. The whole matter requires further examination. The perfection of the standard also requires additional data for certain of the ages.

HEREDITY OF MENTAL TRAITS

Banker has completed his investigations into family likeness in scholastic achievement, based upon the school records in the Huntington school of different members of the same family. This study was made on some thirty or forty families.

Complications appeared owing, in part, to the different methods of grading students as employed by different generations of teachers. This difficulty was fairly well met by a special device, as explained in earlier Year Books. By extension of these methods, Banker has made it possible to compare achievements of the same individual all the way from the primary school to college and universities. His researches have led him into a somewhat pessimistic attitude in regard to the possibility of determining the genetic mental constitution of an individual from his scholastic records. Nevertheless, some of his studies have revealed a similarity of high grades in particular studies obtained by close relatives. This result is not uniform enough to be very convincing of the genetical factors present.

Banker also stresses the insufficiency for genetic analysis of methods as yet devised for measuring mental traits, or the genetical factors that determine such traits.

THE INHERITANCE OF SPORADIC GOITER

While Dr. Tage Kemp was a guest of this Department during the autumn of 1932, he made an investigation of a family on Long Island showing sporadic goiter. His study of the distribution of goiter in this family, together with a consideration of its distribution in other published pedigrees, leads him to the conclusion that the most reasonable interpretation is that hereditary sporadic goiter depends upon a dominant gene that is located in an X-chromosome and causes not only the development of goiter but also non-disjunction of the two X-chromosomes in the female. Besides this sex-linkage it is reasonable to suppose that sex limitation also occurs. If we assume, as in *Drosophila*, that in this type of non-disjunction exceptions from the general rule appear in such a way that the non-disjunction of the 2 X-chromosomes does not occur, then there might arise occasional goitrous families in which normal females have normal daughters and males which are conductors or are goitrous themselves. Such occasional goitrous males have been recorded in families of sporadic goiter.

GEOPHYSICAL LABORATORY¹

ARTHUR L. DAY, DIRECTOR

PROGRESS IN CRYSTALLOGRAPHY²

In 1912 a new major line of development began in crystallography, initiated by the discovery of von Laue in collaboration with Friedrich and Knipping, that the planes of atoms in crystals are capable of diffracting X-rays and thereby of revealing the inner structures of crystals. This method of attack was soon developed extensively by Sir W. H. Bragg and W. L. Bragg, followed by numerous other workers, and the precise spatial arrangements of the atoms in many crystals were established. In the new developments the older experimental crystallographic laws were confirmed and extended. The older crystallographers' hypothesis that crystals are structural discontinua arranged in the 230 patterns of the space groups was also confirmed and the 230 space groups were found to be indispensable in deciphering the arrangements of the constituent atoms in most crystals.

Before the application of röntgenographic methods, chemical crystallography had achieved many notable results but had at length come to barriers nearly or quite impenetrable with the then available methods. Who could tell, for example, why lead is soft and steel is hard, or why SnO_2 (tinstone) crystallizes in tetragonal prisms while SiO_2 (quartz) crystallizes in hexagonal prisms, notwithstanding the strict analogy between the chemical formulæ of the two compounds?

In the attempt to answer these and similar questions, V. M. Goldschmidt and his coworkers from 1923 onward have carried out a series of studies with the aid of röntgenographic, petrographic and chemical methods beginning with substances of the very simplest composition and investigating a whole series of compounds of each successively more complex formula type. The results of these investigations have been the growth of a new science of crystal chemistry in which it is possible in many cases to predict the properties of new crystalline compounds and to synthesize crystalline compounds with designated or desired properties. Simultaneously new fields of application of crystallographic results have opened in technology and industry and the interaction between the pure and applied aspects of the subject is a constant stimulus to further progress.

Information regarding the underlying mechanisms of isomorphism and polymorphism disclosed by the new crystallography has been of great value in petrography and geochemistry. Thus an explanation has been afforded why certain rare elements such as rubidium and caesium do not form accumulations in rocks of any type and their compounds do not occur as individual minerals, whereas the equally rare elements, niobium, tantalum, and the rare earths form extensive accumulations in rocks of a certain type (pegmatites) and many of their compounds occur as individual minerals in these rocks.

¹ Situated in Washington, District of Columbia.

² Bart, Tunnell, Ksanda.

In this Laboratory the study of such isomorphous series as the spinels,¹ the cristobalite-like compounds¹ (high-cristobalite, α -carnegieite, $\text{Na}_2\text{CaSiO}_4$), and the sodalite-like compounds² (sodalite, noselite, hauyne, lazurite, the ultramarines) has cleared up the question of their chemical constitution (chemical formulæ) and brought forth a new principle for the analysis of the crystal structures of pure compounds, the principle of variate atom equipoints. This principle has already been found applicable to a considerable number of compounds, the structures of which were formerly in doubt.

By analyses of the crystal structures of sodium nitrate³ and ammonium nitrate⁴ at elevated temperatures in this Laboratory, it has been found possible to verify the hypothesis that the nitrate-groups are rotating around the central nitrogen atom. The hypothesis that certain molecules are rotating in the crystalline state was introduced by L. Pauling. From considerations based on a wave-mechanical treatment of the problem of a diatomic homopolar molecule free to rotate in an axially symmetrical field of force, Pauling was able to demonstrate the possibility of molecular rotation within a crystal lattice. In the case of sodium nitrate, however, Brandenberger has pointed out that there is one particular stationary position of the nitrate-group that would be very difficult to discriminate from a rotating nitrate-group. It is of considerable interest, therefore, that potassium nitrate⁵ has been found to exhibit both these structures in different polymorphic modifications. In potassium nitrate, röntgenographic analysis is clearly able to differentiate the two crystal structures.

For future work in chemical crystallography it is particularly desirable to have suitable methods for studying efficiently the structures of crystals of lower symmetry, especially monoclinic crystals, since nearly half of the members of the crystal kingdom belong to this one system. Early work on crystal structures was chiefly concerned with crystals of higher symmetry, partly because the structural calculations are somewhat simpler and partly because the chemical elements and compounds of simplest composition which were investigated first mostly crystallize in the systems of higher symmetry. For the solution of such structures relatively simple methods and apparatus sufficed. In the future, however, an increasing proportion of crystal-structure investigations will be concerned with crystals of lower symmetry, and in this work more powerful and elaborate apparatus is indispensable. Fortunately, powerful techniques for the study of crystals of lower symmetry are now available. The most important of these at present are based on the Weissenberg X-ray goniometer and the ionization-chamber spectrometer. The ionization-chamber X-ray spectrometer was invented and applied some time ago by Sir W. H. Bragg and W. L. Bragg and has since led to important results in the hands of numerous investigators. The X-ray goniometer was invented by Weissenberg in 1924, and he also deduced the necessary equations for evaluating X-ray goniometer photo-

¹ Barth and Posnjak.

² Barth.

³ Kracek, Posnjak, Hendricks.

⁴ Hendricks, Posnjak, Kracek.

⁵ Barth, Ksanda, Kracek.

graphs. The numerical evaluation is somewhat lengthy, however, and for nearly all purposes can be replaced by the extremely simple and useful graphical method devised by Schneider.

By the use of the Weissenberg goniometer and the graphical construction of Schneider, the crystal structures of ilmenite (iron titanate)¹ and tenorite (cupric oxide)² have recently been completely determined in this Laboratory. In these two studies the Weissenberg goniometer proved itself extremely helpful and it is improbable that the data necessary for a satisfactory proof of the structures could have been obtained by other methods. At the present time sylvanite and calaverite, two monoclinic tellurides of gold and silver, are being investigated and it is hoped that a solution of their structures will throw additional important light on the still not completely solved problem of the relation between external form and internal structure.

In the Weissenberg goniometer a small crystal or crystal fragment suffices and, indeed, is most suitable, whereas in the ionization-chamber method for accurate results a much larger crystal is required. Where large crystals (greater than 1 cm. in minimum diameter) are available, the quantitative measurements of intensities afforded by the ionization-chamber spectrometer are of the utmost value in the study of structures in which the locations of the atoms involve many parameters (variables). The ionization-chamber measurements in these cases can be supplemented, however, by estimates of relative intensities on Weissenberg photographs. After measurement of the absolute intensities of many orders of reflections from a few important planes, the relative intensities of many orders of reflections from many other planes can be quickly obtained from Weissenberg photographs. The use of the Weissenberg X-ray goniometer in conjunction with the ionization-chamber spectrometer should materially reduce the labor of structural determinations in crystals with many parameters and of lower symmetry.

STUDIES ON ALKALI SILICATES ³

According to the compilations of Clarke and Washington, the abundance of sodium and potassium in the rocks of the Earth's crust is of about the same magnitude as that of calcium and magnesium; the other three alkalis (lithium, rubidium and cæsium) form only a relatively small proportion of the whole. In the rock minerals the alkalis occur in combination with alumina and silica, together with some of the other oxides, in feldspars, micas, nephelites, pyroxenes. On the other hand, the alkalis rarely occur as silicates alone; this is partly because the complex compositions of magmatic and other natural solutions in general rarely favor the crystallization of the pure alkali silicates; partly also because these silicates have relatively high solubilities in water, and hence do not resist weathering. These occurrences of the alkalis in rock minerals have accordingly made it desirable to determine the conditions under which the various alkali silicates are capable of existence, as a useful adjunct to the investigations upon the stability relations among the more prominent mineral series that occur in nature.

¹ Barth, Posnjak.

² Tunell, Posnjak, Ksanda.

³ Kracek.

Such systematic studies are further needed in correlating the properties and occurrence of silicates in general from another point of view. It is known that, in consequence of the periodic relations among the elements, there are systematic progressions in properties when one element replaces another in a given type of chemical compound or solutions of such compounds. Thus, the melting curves of cristobalite (the high-temperature modification of silica) show a progressively increasing tendency to deviate from what might be described as normal behavior in the silicate melts, the constituents of which are (1) silica (SiO_2) and (2) an oxide of one of the following elements in the order Cs, Rb, K, Na, Li, Ba, Sr, Ca and Mg. With the last three the abnormality becomes so large as to give rise to the

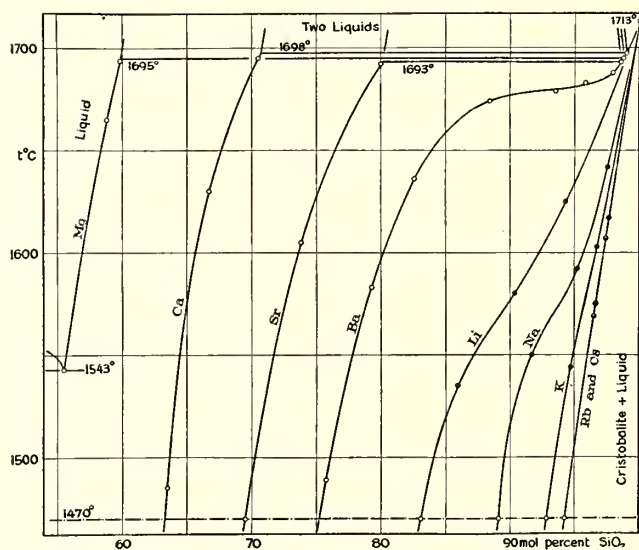


FIG. 1—Liquidus relations for cristobalite in the alkali and alkali earth silicate systems.

formation of two immiscible liquid layers. These relations are represented in figure 1 where we have plotted the melting temperatures along one axis against the molecular compositions of the melts along the other axis.

A sufficient amount of data has now been collected at the Laboratory to enable us to compare most of the stability relations of the crystalline phases among the first four alkalis, Li, Na, K and Rb. These relations are represented graphically in figure 2, again plotting melting temperatures as a function of the molecular composition. Only the general features of the individual systems are represented, since any further detail would confuse the diagram unduly.

Inspection of this figure reveals certain notable regularities. The melting points of the known compounds change progressively from one system to another. The values of these are collected in table 1. Of interest is the fact that among the alkali metasilicates the melting points fall regularly from lithium to potassium, whereas among the disilicates, lithium occupies an apparently anomalous position with its disilicate melting at 1033° , while

the disilicate of sodium melts at 874° , and those of potassium and rubidium show a regular progressive rise. Potassium is the first element to form a tetrasilicate. We may note here by way of comparison that among the alkaline earths (Mg, Ca, Sr, Ba) the tendency toward forming more highly siliceous crystalline compounds also increases in the order of increasing atomic weights of the base constituent; all have highly stable orthosilicates, but only barium forms a disilicate. (The sequences of the melting points

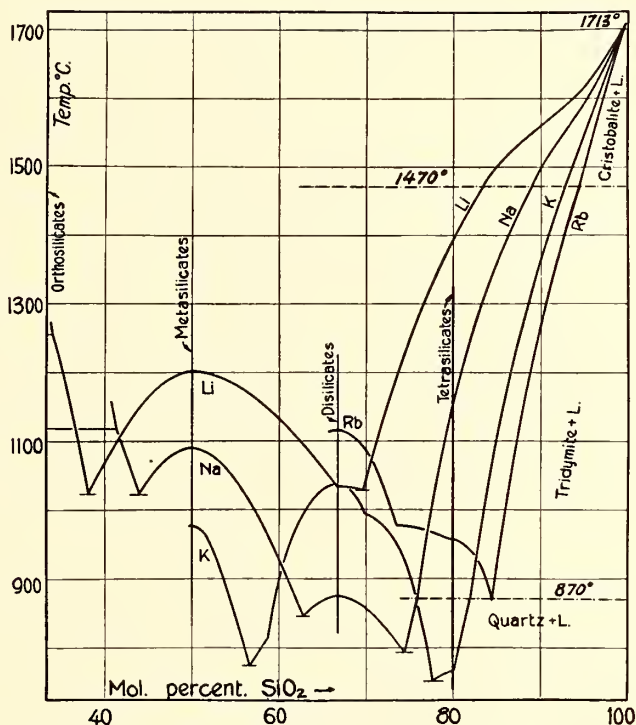


Fig. 2—Melting relations in the alkali silicate systems.

of the alkali earth silicates are also worthy of note.) Another feature of the alkali silicate systems is the existence of solid solutions (mixed crystals) in the disilicate region. The distinguishing feature of these solid solutions is that as the compound crystallizes, an excess of the base constituent or of silica goes into the crystal, depending upon the composition of the melt.

The existence of these solid solutions is especially well defined in the ternary system of sodium and potassium silicates, illustrated in figures 3a and 3b. This is petrologically the most important ternary system involving the alkali silicates alone. As can be seen from the diagram, there are no ternary silicates of these two bases. Sodium and potassium metasilicates form a simple eutectoid system, as is also true in a measure of the disilicates. The latter compounds, however, present a somewhat more complicated relationship in consequence of the solid solution formation. At a certain temperature, characteristic for each given composition in the system, these solid solutions *unmix*, yielding the *pure* disilicates which then exist at all

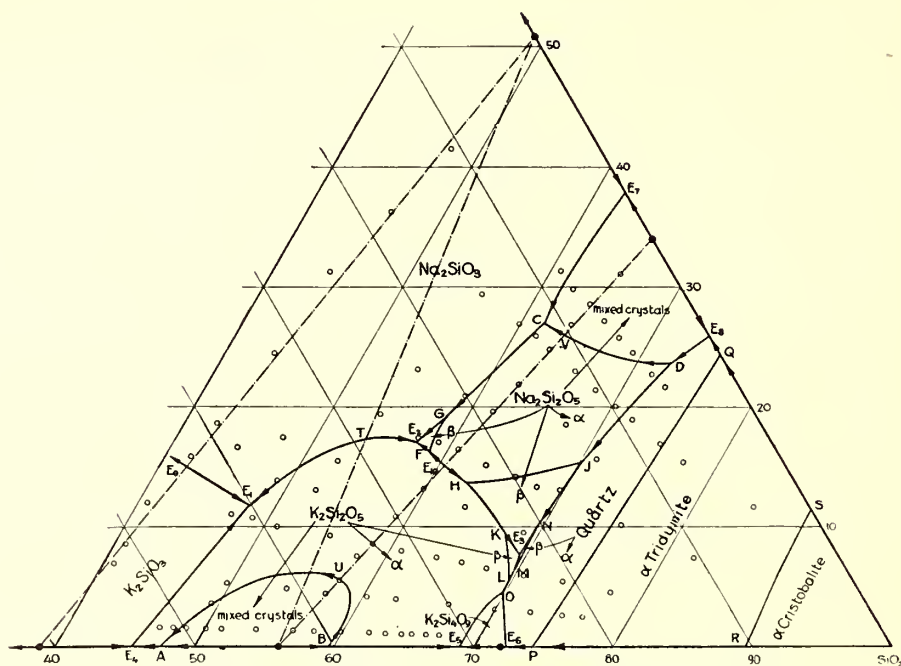


FIG. 3a—The ternary system, Na_2SiO_3 - K_2SiO_3 - SiO_2 , indicating the field boundaries and the courses of crystallization.

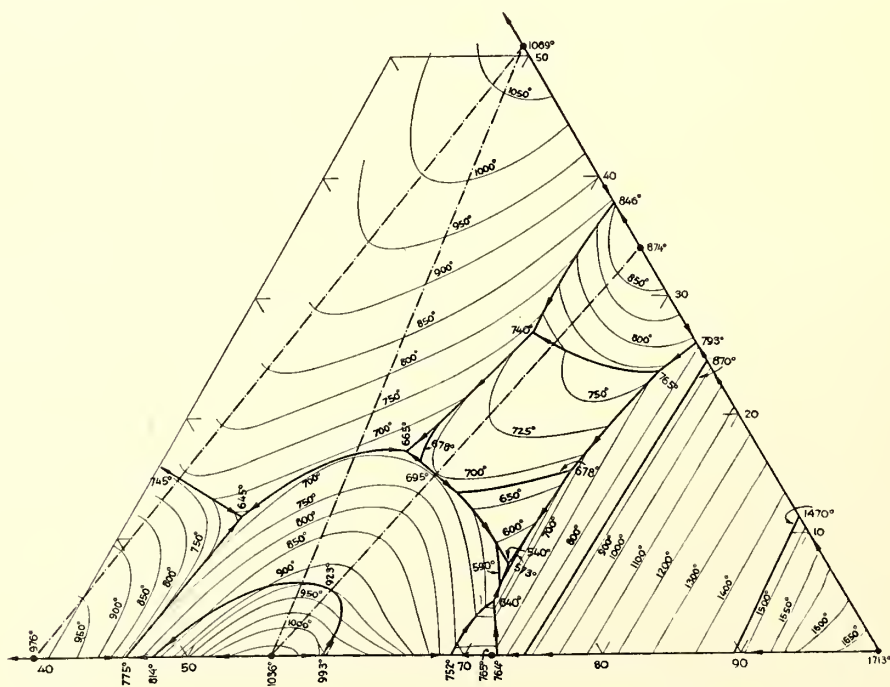


FIG. 3b—The ternary system, Na_2SiO_3 - K_2SiO_3 - SiO_2 , indicating the course of the isotherms.

lower temperatures. This unmixing takes place at a series of temperatures in the ternary system, yielding screw curves for the boundaries between the solid solution regions and the regions of existence of the pure disilicates (curves AUB and CVD, figure 3a).

TABLE 1—*Alkali silicate melting points*

	Temperatures °C			
	ortho	meta	di	tetra
Li.....	1255*	1201	1033	.....
Na.....	1118*	1089	874	.....
K.....	.....	976	1036	765
Rb.....	.....	.....	1155	955

* Denotes incongruent melting.

Potassium tetrasilicate occupies only a small portion of the above-mentioned ternary system. This compound is noteworthy for the fact that *pressure* lowers its melting point relatively rapidly 60° per 1000 bars). The consequence of this effect of pressure upon the melting point in the binary system, potash-silica, is to suppress the stable existence of potassium tetrasilicate in equilibrium with molten silicate solutions at all pressures in excess of 1250 metric atmospheres.

BY-PRODUCTS—GLASS¹

Valuable insight into the fundamental geological problem of the differentiation of rock magmas and the origin of the igneous rocks has been obtained from the numerous phase-equilibrium studies which have been carried out at the Geophysical Laboratory. The primary object of these studies has been their application to geological problems, but the applications of a few of them to technological problems during the period of the World War proved to be of great practical utility then and has since been an important by-product of the work of the Laboratory. An illustration of this is the system, $\text{Na}_2\text{O} \cdot \text{SiO}_2 - \text{CaO} \cdot \text{SiO}_2 - \text{SiO}_2$, which lies at the very foundation of the glass-maker's art.

The first requirement for a glass is that it can be cooled from the molten condition to ordinary temperatures without crystallizing, *i.e.* without attaining to the equilibrium which characterizes the same group of substances in rock formation. Several oxides can be prepared in the glassy condition, and within limited ranges of composition each of these can be admixed with other oxides, but only silica and the silicate glasses fulfil the requirement that to be industrially useful glasses must be resistant to water and acids. Pure silica yields an excellent glass, but its melting point is so high (1700°+ C.) and the viscosity of the liquid at the melting point is so great that it can not be manufactured in commercial quantities. A flux must be added to lower the melting temperature and reduce the viscosity.

¹ Morey.

The best and cheapest flux is soda, giving the system, $\text{Na}_2\text{O}-\text{SiO}_2$. A study of this system revealed a hitherto unknown compound, sodium disilicate, which with quartz yields a eutectic melt at 793° containing 73.9 per cent SiO_2 by weight. In other words the addition of 26 per cent of Na_2O has thus served to lower the melting point of pure silica by almost 1000° C. Glass of this composition (74 per cent SiO_2 , 26 per cent Na_2O) can be manufactured without difficulty, but is not suitable for most purposes because it is readily dissolved by water. This limitation, however, has itself been turned to commercial account in the development of the large water-glass industry.

To render the sodium silicate less soluble and so to make it commercially available for the ordinary uses to which transparent glass is put, other oxides must be added. Lime is the most common of these, both because of its cheapness and of the excellence of the product obtained with it.

The phase-equilibrium diagram of the ternary system, sodium metasilicate-calcium metasilicate-silica, shows the existence of three compounds containing all three components, namely, $2\text{Na}_2\text{O}.\text{CaO}.3\text{SiO}_2$, $\text{Na}_2\text{O}.2\text{CaO}.3\text{SiO}_2$, and $\text{Na}_2\text{O}.3\text{CaO}.6\text{SiO}_2$, but only the last of these is of importance in glass manufacture. This compound, to which has been given the name "devitrite," is the crystalline phase characteristic of commercial soda-lime-silica glasses, and these make up by far the greatest proportion of commercial glassware. Like silica, devitrite shows little tendency to crystallize, but every mixture in which it is the primary phase has a low freezing point and a high viscosity at the freezing point, which explains why glasses in this composition range can be melted on a commercial scale without devitrification.

The lowest freezing temperature reached in this series of compositions falls at the ternary eutectic between devitrite, sodium disilicate and quartz, at 725° , and this low-melting eutectic dominates the common glass compositions. All successful soda-lime-silica glasses must have a composition near this low-melting eutectic, in the field of devitrite, which slopes gently up from it. As soon as the composition of a glass departs from this field it either becomes too easily decomposed by water or it crystallizes too readily to be a successful commercial product, or both faults are present.

Thus the phase equilibrium studies have furnished to us the authentic explanation why the composition of glasses must be held within a narrowly restricted range, and why within such a range it is possible to manufacture a material of such unique physical properties on a conveniently large scale.

These physical properties when compared with those of other familiar solids (salts, minerals, metals) are indeed remarkable. While obviously solid when cold, glass is a material which on cooling from a thin molten condition increases continuously in viscosity until it becomes hard and brittle, but remains, nevertheless, a liquid—an undercooled liquid. The chemical properties of the undercooled liquid are those of a mutual solution of the various component oxides, and are not those of the silicate compounds which would crystallize from it if time and conditions permitted them to do so. This is shown by the change of density with composition. The

lines of constant density are continuous curves, which sweep unchanged over the compositions of compounds, boundary lines and eutectics.

The series of measurements,¹ of which these are a part, includes measurements of refractive index and dispersion and is the most extensive and complete ever made on a ternary system. An excellent test is afforded of the various formulæ which have been proposed for the relationship between refractive index and density. The simple formula of Gladstone and Dale still fits the facts better than any of the formulæ later proposed.

VOLCANO STUDIES

There are many who still recall the great catastrophe of 1902 when Mont Pelée, Martinique, broke out in violent eruption, destroying the City of Saint Pierre and all of its inhabitants to the number of some 30,000.

Although the studies made at that time by Lacroix, by Anderson and Flett, by Heilprin and by many others were both extensive and thorough, they were undertaken amid the greatest difficulties because of the violence of the eruption and the persistent threat to human life. The eruption was characterized by two very uncommon volcanic phenomena; (1) the nuées ardentes, one of which destroyed the City of Saint Pierre at a single blast and all of which remained inaccessible to close study because of their extreme violence; (2) the great spine which rose above the crater to a height of 1000 feet or more while still at a very high temperature and then disintegrated before it was cool enough for close study.

It is probably much less well known that Mont Pelée has also been more or less continuously active during the past three years. The present eruption has been of much less violence than the earlier one, but has, nevertheless, again presented the same unusual phenomena, including nuées ardentes of considerable violence and successive small spines developing at the summit crater. In many respects the opportunity for study on the present occasion has been much more favorable than on the previous one, but lacking spectacular events it has failed to attract so large a number of students. It is fortunate that Mr. F. A. Perret, Research Associate in Volcanology of the Carnegie Institution of Washington, and one of the most experienced students of the subject in this generation, has been on the ground at Mont Pelée during the entire period of present activity. His forthcoming report is too long for competent review in this place, but is expected to be published during the coming winter.

PUBLICATIONS

(805) A metal X-ray tube for characteristic radiation. C. J. Ksanda. *Rev. Sci. Instr.* 3, 531-534. 1932.

This paper describes a metal X-ray tube of the gas-filled type. Its salient features are simplicity of construction and ready interchangeability of the anticathode, which permits the use of different kinds of characteristic radiation. For purity of homogeneous X-radiation and intensity of emission, this tube has distinct advantages in crystal-structure analysis. The method of operation is notable for its convenience and absence of complicated control devices. A mechanical vacuum pump is connected with the tube, the gas

¹ Morey, Merwin.

pressure being regulated by the setting of an adjustable needle valve. In the operation of the tube, the valve is adjusted so that the gas pressure is of the desired magnitude. Voltage across the electrodes is limited by a spark gap placed in parallel with the tube; the distance between the needle points measures the working voltage of the tube.

(806) The structures of the minerals of the sodalite family. Tom. F. W. Barth. *Z. Krist.* 83, 405-414. 1932.

There are in Nature three well-known minerals belonging to the sodalite family: Sodalite, $\text{Na}_8\text{Al}_6\text{Si}_6\text{O}_{24}\text{Cl}_2$, noselite, $\text{Na}_8\text{Al}_6\text{Si}_6\text{O}_{24}\text{SO}_4$, hauyne, $(\text{Na}, \text{Ca})_{4-8}\text{Al}_6\text{Si}_6\text{O}_{24}(\text{SO}_4)_{1-2}$. In all these three silicates a "framework" of composition $(\text{Al}_6\text{Si}_6\text{O}_{24})^{6-}$ forms the skeleton of the crystalline edifice; within that framework there are large open spaces partly occupied by the bulkier atoms of the compounds, like Na^{1+} or Cl^{1-} .

There are three things that make the result of this structure analysis worthy of special notice: first, mineralogists have been unable to assign to hauyne any general chemical formula; the present X-ray study has now definitely settled this question; second, it can be disproved that extra ions with no fixed positions are wandering about in the lattice. This hypothesis of the so-called errant constituents was introduced by Jaeger and it has been partially adopted by other X-ray workers, and it has entered into the speculations concerning the structure of zeolites and other silicates; third, in order to work out these structures one has to apply the principle of the variate atom equipoints, which was introduced not long ago (Barth and Posnjak, paper No. 752, 1931) and in a number of subsequent cases has proved itself a most useful tool in X-ray analysis.

This paper also sheds new light on the compositions of the ultramarines. The true composition of the "framework" that is supposed to be the underlying skeleton in all ultramarines is $[(\text{Al}, \text{Si})_{12}\text{O}_{24}]^n$ in each unit cell. This formula enables us to understand the mechanism that conditions the great variation in the content of silica, alumina and sulfur without thereby influencing the structural features of the various ultramarines. The great extent of chemical variation in this system should therefore no longer surprise us.

Undoubtedly there remains more work to be done before every particular of the very complex chemistry of the system of ultramarines is solved, but the principles that govern the chemistry of these compounds have been disclosed through the present X-ray study.

(807) Isotopes of uranium, thorium, and lead, and their geophysical significance. Charles Snowden Piggot. *Phys. Rev.* 43, 51-59. 1933.

In the determination of geologic time by the ratio existing between the uranium in any given mineral and the lead produced from it by radioactive disintegration, the chemical analysis of the mineral gives all the uranium and all the lead found. This lead may have come from several sources. However, the mathematical formula, setting forth the relation in time existing between a unit mass of uranium and its corresponding lead, represents a particular isotope of uranium and that particular isotope of lead produced by it.

In order to obtain the particular substances involved in the mathematical formula, an effort was made to ascertain the number and relative amounts of the isotopes of uranium and of lead. This effort was extended to include the isotopes of all the elements involved, *i.e.* those from atomic numbers 81 to 92.

The data obtained indicate that the various elements involved possess isotopes as follows: uranium 8, thorium 8, radium 4, bismuth 14, lead 16 and thallium 8. A suggested arrangement of these substances places them in four radioactive series beginning with eight isotopes of uranium, there being two to each series, and ending with sixteen isotopes of lead, with four to each series. This arrangement implies that thorium is derived from an isotope of uranium. The relations of the constituent isotopes of uranium to those of lead in a mineral are more complex than previously supposed and vary somewhat from mineral to mineral. Ordinary lead and radio-derived lead possess different isotopic compositions though both apparently derive from the same ultimate source. The isotopic composition of a certain lead depends upon the isotopic composition of the uranium at the time of incorporation in the mineral and upon the length of time that mineral has existed. Apparently the isotopic composition of lead changes with its age. The most accurate age determination would be obtained by confining the calculation to the uranium isotope of mass 238 and the lead isotope of mass 206 which is derived from it.

(808) Crystals of iron-rich pyroxene from a slag. N. L. Bowen. J. Wash. Acad. Sci. 23, 83-87. 1933.

Crystals formed in a slag during the cooling of a reverberatory furnace of the United Verde Copper Company, Clarkdale, Arizona, have been examined optically and crystallographically. The crystals are monoclinic: $a:b:c = 1.0786:1:0.5828$; $\beta = 71^\circ 31'$. The plane of the optic axes is parallel to b (010) and the extinction angle ($c \wedge \gamma$) = $+36^\circ$. The refractive indices are $\gamma = 1.785$, $\alpha = 1.745 \pm 0.003$. The optic axial angle $+2V = 20-25^\circ$.

The crystals have, approximately, the composition FeSiO_3 82 per cent, CaSiO_3 8 per cent, MgSiO_3 10 per cent. They are thus much richer in iron than any pyroxene yet described and serve to extend our knowledge of the great group of monoclinic pyroxenes into a composition range hitherto unknown.

(809) Vogtite, isomorphous with wollastonite. N. L. Bowen. J. Wash. Acad. Sci. 23, 87-94. 1933.

Vogtite is a silicate formed in slags and shown by Hallimond to have the general formula $(\text{Ca}, \text{Fe}, \text{Mn}, \text{Mg})\text{SiO}_3$. In the Hallimond example Ca exceeded any one of the other basic elements, but was very much less than their sum. Both Hlawatsch and Hallimond made crystallographic studies and found the crystals to be triclinic. Their measurements of interfacial angles agree, but Hallimond chose a different orientation from that previously chosen by Hlawatsch with correspondence only in the position of the c axis (prism zone).

If vogtite is oriented in such a way that the prism zone corresponds with the ortho-zone of wollastonite, a remarkable agreement is found in forms and angles of the two species. Wollastonite itself, as a result of X-ray studies, is now known to be triclinic and its new constants have been determined. Vogtite is therefore to be referred to a similar system of axes. The values are:

Wollastonite $a : b : c = 1.083 : 1 : 0.967$, $\alpha = 90^\circ$,
 $\beta = 95^\circ 16'$, $\gamma = 103^\circ 25'$

Vogtite $a : b : c = 1.076 : 1 : 0.964$, $\alpha = 90^\circ 43'$,
 $\beta = 95^\circ 10'$, $\gamma = 103^\circ 35'$

The isomorphism of wollastonite and vogtite is of interest in connection with the problem of bustamite. Although isomorphism alone does not necessitate the existence of solid solution, there are the strongest reasons for believing that vogtite is simply a wollastonite solid solution and the likelihood that bustamite is also a wollastonite, as Sundius maintains, becomes very great.

(810) The ternary system, K_2SiO_3 - Na_2SiO_3 - SiO_2 . F. C. Kracek. *J. Phys. Chem.* 36, 2529-2542. 1932.

The liquidus relations in this system, determined by the method of quenching, comprise the stability fields of the various modifications of silica (quartz, tridymite, cristobalite), the disilicates, $Na_2Si_2O_5$ and $K_2Si_2O_5$, the tetrasilicate, $K_2Si_4O_9$, and the metasilicates, K_2SiO_3 and Na_2SiO_3 . No ternary compounds were found to exist in the system. Particular interest attaches to the unique type of solid solution relations of the disilicates and to the polymorphic relations of the compounds, $Na_2Si_2O_5$, $K_2Si_2O_5$, $K_2Si_4O_9$, and of the various modifications of silica. In addition to the component binary systems along the binary boundaries there are three binary systems within the ternary system, namely: K_2SiO_3 - Na_2SiO_3 , $K_2Si_2O_5$ - $Na_2Si_2O_5$, and $K_2Si_2O_5$ - Na_2SiO_3 . Complete data for the system are given in tables which can not be reproduced here. Attention may be directed, however, to the relatively low liquidus temperatures in the major portion of the system and to the sluggishness of crystallization in compositions lying in the quartz, the $K_2Si_4O_9$, and certain portions of the disilicate fields, that is, in compositions which form the basis of certain types of commercial glasses. The results are of interest in petrology in that they furnish a basis for the study of multi-component systems containing other mineral-forming oxides of geochemical significance.

(811) Radium content of ocean-bottom sediments. Charles Snowden Piggot. *Am. J. Sci.* 25, 229-238. 1933.

The radium content of twenty-eight (twenty-seven from the Pacific) samples of ocean-bottom sediments was determined, and similar determinations reported by Joly and Pettersson are included for comparison. These comprise practically all such determinations that have been made, and the paucity of these data in comparison with the extent, importance, and high radium content of the material is emphasized. Those bottoms composed mostly or entirely of "red clay" generally contain more radium. A mechanism for explaining the high radium content of deep-sea sediments is suggested which does not coincide with the opinions of either Joly or Pettersson.

(812) Thermel technic. Walter P. White. *Rev. Sci. Instr.* 4, 142-146. 1933.

Thermels (thermoelectric thermometers), which have supreme precision in differential readings, will also read temperature differences up to 30° consistently to about 0.0001° , and this includes reading ordinary temperatures to 0.0002° against ice baths. A prevailing impression that errors much larger than this are inevitable proves to be unjustified when proper technic is used.

Inhomogeneity in the wire, the only source of error peculiar to the thermel, is generally supposed to be very serious, and so it is at high temperatures, where the largest amount of work has been done with thermels. But for very precise measurements at room temperature it does not prevent getting the precision stated above. It merely demands a systematic, but not at all difficult or troublesome, control of temperature distribution, since both

inhomogeneity and change in temperature distribution are necessary to cause this sort of error.

Electrolytic leakage, due to insufficient insulation, is a threat in humid weather, since an insulation resistance of thousands of megohms is often needed. But this threat can be defied by the following easy precautions: (1) Dry the thermel out thoroughly, perhaps at 130° ; (2) seal the case with a wax having no electric surface leakage in the dampest weather, and have equally good insulation for the terminals, switches and leads; (3) have sufficient means for testing the adequacy of these two measures, as by putting 40 volts in series with the insulation and a very sensitive galvanometer with sufficient safety resistance.

Vagabond electromotive forces, due to various types of leakage and to thermoelectric action, must have their effects eliminated, as in all work with sensitive galvanometers. With thermels this can be done by switches which also test for the errors discussed above, thus facilitating their avoidance. Special types of switches can be used, having practically no leakage or vagabond electromotive forces themselves.

(813) Strukturen mit ungleichwertigen Atomen in gleichwertigen Punktlagen. Tom. F. W. Barth. Fortschritte Mineral. Krist. Petrog. 17, 25-27. 1932.

In this paper, which was presented before the annual meeting of the Deutsche Mineralogische Gesellschaft in Frankfurt am Main, September 1932, it is pointed out that the interpretation of the results of certain crystal structure researches recently conducted in this Laboratory demands an expansion of the theory of space groups, and it is shown that structurally equivalent positions in the space-lattices of crystalline chemical compounds are not necessarily occupied by chemically equivalent atoms. By the application of this principle to special cases it is demonstrated that several previously encountered difficulties of reconciliation of experimental data with the formal theory of space groups disappear. Eight actual examples are quoted and explained.

(814) Zeolitic alteration of pyroclastics. M. M. Bramlette and E. Posnjak. Am. Mineral. 18, 167-171. 1933.

The frequent alteration of vitric pyroclastics to clay materials, of which montmorillonite is the most abundant, has been well established and bentonite is recognized as a rock name for such material. This paper points out that the mineral clinoptilolite, which may be included with the zeolites, is also a common alteration product of pyroclastics where the alteration is less complete. This mineral seems to be an intermediate product in the process of alteration of the volcanic glass, with the clay mineral an end product of the process.

(815) The system, $\text{Ca}_2\text{SiO}_4\text{-Fe}_2\text{SiO}_4$. N. L. Bowen, J. F. Schairer, and E. Posnjak. Am. J. Sci. 25, 273-297. 1933.

The system, $\text{Ca}_2\text{SiO}_4\text{-Fe}_2\text{SiO}_4$, has been studied thermally by using iron crucibles as containers and an atmosphere of nitrogen to prevent oxidation. Even in the presence of metallic iron not all of the iron oxide of these mixtures is reduced to the ferrous state, but an equilibrium is established when there is still a small amount of Fe_2O_3 . Accurate presentation of the results requires a ternary diagram in order to show the presence of this small amount of Fe_2O_3 . A great gain in the utility of the results is made if the small amount of Fe_2O_3 is calculated as FeO and thus all the iron oxide expressed as FeO . We then obtain a binary diagram from which temperatures and

compositions are easily read. The diagram shows that there is one intermediate compound, *viz.* CaFeSiO_4 , which melts at $1208 \pm 2^\circ$ and forms a complete series of solid solutions with fayalite which melts at $1205 \pm 2^\circ$. The solid solution series is of the type with a minimum (Type III, Roozeboom) and the minimum is at $1117 \pm 3^\circ$, with the composition 81 per cent Fe_2SiO_4 .

In addition CaFeSiO_4 and $\beta\text{-Ca}_2\text{SiO}_4$ form a series of solid solutions of the type with an hiatus and with all melting temperatures intermediate between those of the end members (Type IV, Roozeboom). At the Ca_2SiO_4 end of the diagram the melting temperature rises to 2130° .

The existence of these solid solutions is confirmed by both optical and X-ray evidence.

The results are discussed in connection with certain problems of the petrologist and of the metallurgist.

(816) The crystal structure of tenorite (cupric oxide). G. Tunell, E. Posnjak, and C. J. Ksanda. *J. Wash. Acad. Sci.* 23, 195-198. 1933. (Preliminary report.)

The crystallographic elements and crystal structure of tenorite were determined by means of the Weissenberg X-ray goniometer. Tenorite is monoclinic and belongs to the space group $C2/c(C_{2h}^6)$. The atoms are arranged in a four coordination, each oxygen being surrounded by four copper atoms at the corners of a non-equilateral tetrahedron, and each copper being surrounded by four oxygens lying in a plane at the corners of a rectangle. The oxygen atoms are situated on symmetry axes and have one parameter; the copper atoms are located on symmetry centers (fixed positions).

(817) Extra specific heat in cuprous sulfide; specific heat of ferrous oxide. Walter P. White. *J. Am. Chem. Soc.* 55, 1047-1053. 1933.

A relatively pure sample of mineral Cu_2S was used and synthetic FeO . The highest temperature was 900° . Enclosure against the air was needed in heating these materials, and the only available method was with silica glass. The resulting technical requirements diminished precision. To offset this inevitable disadvantage, the furnace temperature was given superior uniformity by means of special, separately heated, end plugs. The final precision was about 1 per mille at the higher temperatures, which is about as good as has yet been obtained without the disadvantage of the silica glass enclosure.

The splash and steam production when the heated specimen is dropped into the calorimeter has been a troublesome, though not always serious, feature of this kind of calorimetry. Its difficulties were, apparently, completely overcome by combining two excellent schemes which hitherto have been used only singly. These are, first, a tall, narrow cup for receiving the hot body and submerging the steam and, second, a quickly closing shutter or trap in the calorimeter cover. The combination, giving almost perfect results, is still very easy to install.

The heat required to raise Cu_2S through successive temperature intervals was found to be:

Interval	Calories per gram
300-400°	14.96
400-500°	13.19
500-600°	12.98
600-700°	12.02
700-900°	2 x 12.82

The specific heat is thus seen to have passed through a maximum below 400° , showing a behavior which is not that characteristic of an inversion, and which is of a sort now known in about two dozen substances.

The "ferrous oxide" sample has been analyzed since the paper was published, and proves to contain more oxygen than was at first supposed. It has the composition of the liquid produced when iron oxide melts incongruently (in contact with metallic iron), that is, 88.31 per cent FeO and [11.69] per cent Fe_2O_3 . On the assumption that the mean atomic heat of this mixture is the same as that of pure FeO , 1.44 per cent should be subtracted from the specific heat, as determined, to get that of pure FeO , and the experimental results reduce to $c_p = 0.17256 + 0.0000266t$, which holds from 700° to 900° , and is extrapolated outside of that interval. It has the peculiarity of being relatively high, but with a relatively small increase with temperature, for an oxide of a heavy metal.

(818) The ternary system, Na_2SiO_3 - $\text{Na}_2\text{Si}_2\text{O}_5$ - NaAlSiO_4 . C. E. Tilley. *Mineralog. petrog. Mitteilungen (Z. Krist., Abt. B)* 43, 406-421. 1933.

The system, Na_2SiO_3 - $\text{Na}_2\text{Si}_2\text{O}_5$ - NaAlSiO_4 , forms part of the more general ternary system, Na_2O - Al_2O_3 - SiO_2 , now under investigation at this Laboratory. The system investigated is comparatively simple and contains no ternary compounds. Of its binary sub-systems Na_2SiO_3 - $\text{Na}_2\text{Si}_2\text{O}_5$ is of simple eutectic type. The binary eutectic, NaAlSiO_4 - $\text{Na}_2\text{Si}_2\text{O}_5$, lies at 71 per cent $\text{Na}_2\text{Si}_2\text{O}_5$ at a temperature of 768°C . and the inversion temperature, carnegieite-nepheline, is unchanged at 1248° . In the system, Na_2SiO_3 - NaAlSiO_4 , solid solution in the high-temperature carnegieite phase leads to a depression of the carnegieite-nepheline inversion to 1163° . The ternary eutectic is placed at a composition, Na_2SiO_3 8.5 per cent, $\text{Na}_2\text{Si}_2\text{O}_5$ 63.5 per cent, NaAlSiO_4 28 per cent, at a temperature of 760° . The petrologic bearing of the laboratory results is discussed, and it is indicated that in norm calculations of certain alkali igneous rocks, sodium disilicate rather than sodium metasilicate is to be preferred as a standard normative constituent.

(819) Determination of the space-lattice of a triclinic mineral by means of the Weissenberg X-ray goniometer. George Tunell. *Am. Mineral.* 18, 181-186. 1933.

In the Weissenberg X-ray goniometer a simultaneous translation of the cylindrical film, coupled with the rotation of the crystal, permits a unique and rigorous determination of the space-lattice, as Weissenberg has stated. In this paper the simple and very useful graphical method of Schneider for the construction of the reciprocal lattice of a triclinic mineral from the measurements on Weissenberg and rotation pictures is explained. The selection of the crystallographic axes is discussed. Lastly the close relation between the elements of the reciprocal lattice (used by X-ray crystallographers) and the polar elements of Victor Goldschmidt is explained and also stated by means of equations.

(820) The space-lattice and optical orientation of chalcantite ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$): An illustration of the use of the Weissenberg X-ray goniometer in the triclinic system. Tom. F. W. Barth and George Tunell. *Am. Mineral.* 18, 187-194. 1933.

By the use of the Weissenberg X-ray goniometer a redetermination of the geometrical elements of the triclinic substance, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, was obtained in close agreement with those previously found by Tutton and by Barker with the reflection goniometer. It was definitely demonstrated that Tutton's choice of the principal or axial directions is most felicitous, since

the interplanar spacings of the three planes chosen as pinacoids by him are now found to be the greatest, second greatest and third greatest, respectively, of any three non-tautozonal planes in the crystal.

The most accurate unit cell dimensions of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ are thought to be those obtained by combining Tutton's angles with our spacing measurements along the three principal axes.

The optical orientation of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ has been redetermined with a Fedorov stage and the results are represented in a stereographic projection. They are in close agreement with the results of Pape.

- (821) Polymorphism in the substituted thiazole, 3-phenyl-2,4-thiazolidione. Optical crystallography of 3-phenyl-2,4-thiazolidione. R. E. Gibson, K. S. Markley, and H. E. Merwin. *J. Am. Chem. Soc.* 55, 2399-2407. 1933.

The compound 3-phenyl-2,4-thiazolidione may melt in a capillary tube either between 143° and 144° or between 146° and 147° C. This phenomenon is accounted for by the fact that the compound may exist in at least two different solid forms, Form I which is stable above *ca.* 100° but which may persist indefinitely in a metastable state at room temperature, and Form II which, although unstable above 100° , may invert so sluggishly to Form I that it actually melts at 143° before the inversion is completed.

Observation of heating curves, thermal expansion, X-ray diffraction photographs and optical properties furnished the experimental basis for the above conclusions.

The optical properties of both forms are almost the same, and in the course of the investigation of the different crystal forms these optical properties were measured with considerable accuracy.

- (822) Phase equilibrium relationships determining glass compositions. George W. Morey. *Ind. Eng. Chem.* 25, 742-748. 1933.

Glasses are undercooled liquids, the term liquid having the technical meaning used in phase equilibrium work. Glasses have passed from the thin molten condition obtaining during their manufacture through a continuously changing sequence of properties, to a hard, brittle substance of sufficient strength and rigidity to be of value in technology. Glass has been known to mankind from the earliest times, and the oldest glasses do not differ markedly in composition from the great mass of glassware today. This is because the particular properties required of a practical glass composition make it necessary that it be not greatly different in composition from the ternary eutectic between the compounds, $\text{Na}_2\text{O} \cdot 2\text{SiO}_2$, $\text{Na}_2\text{O} \cdot 3\text{CaO} \cdot 6\text{SiO}_2$, and quartz, in the ternary system, $\text{Na}_2\text{O}-\text{CaO}-\text{SiO}_2$, because only when of such a composition is it both fluid enough at easily attainable temperatures to be readily melted on a commercial scale and at the same time viscous enough at its freezing point so that devitrification is inhibited. The relation of various complex glasses to this simple eutectic glass is discussed. While we have extensive knowledge of glass composition, we know practically nothing about the constitution of glass.

- (823) The annealing of glass as a physical problem. L. H. Adams. *J. Franklin Inst.* 216, 39-71. 1933.

The fundamental principles underlying the annealing of glass and the present state of knowledge concerning changes in the nature of glass during heating and cooling are briefly reviewed. Emphasis is placed on the fact that a quantitative explanation of the formation and removal of strain

in glass, and a precise determination of the requisite conditions for any desired degree of annealing, may be obtained on a purely mechanical basis, without consideration of the internal constitution of materials in the vitreous state.

An improvement in the definition of annealing time (made feasible by the relatively great speed with which large strains are released) allows a considerable simplification in the determination of the proper procedure for annealing. As an illustration, the procedure for annealing a disk of Pyrex glass, 200 inches in diameter, is given. The best conditions for annealing, when for any reason the temperature must be above or below the most favorable temperature, are also discussed.

It is demonstrated that internal stresses can have no effect on the total volume or on the average density of a block of glass. The stresses may cause a deficiency in density of the interior portion and an excess near the outside, but the mean density of any large or small piece is exactly the same as if the glass were free from stress. Although unannealed glass may have an abnormally low density, the stresses themselves have nothing to do with this effect.

The anomalies of glass in the annealing range, the relation between viscosity and rigidity, the physical basis of the rate of release of strain, and the possibility that glass at low temperatures may have a finite strength are discussed. Although the available data do not yet allow the drawing of positive conclusions, nevertheless the state of aggregation of glass is a problem of very great interest and one to which more attention should be given.

(824) The ray-surface, the optical indicatrix, and their interrelation: An elementary presentation for petrographers. George Tunell. J. Wash. Acad. Sci. 23, 325-338. 1933.

The definitions of terms and the treatments of the elementary principles of optical crystallography in American text-books are in some respects unsatisfactory from the viewpoint of the petrographer. Clear and accurate statements are to be found in Pockels's *Lehrbuch der Kristalloptik*, published in 1906. But Pockels's statements of elementary theory are scattered through mathematical discussions of more advanced problems, and for this reason apparently they have not received the attention that they deserve from American students of petrography. In order to make this material more readily available, the two fundamental theorems of optical crystallography are restated in this paper in very simple geometrical form without mathematical equations, and some of the chief applications of these theorems in petrography are discussed.

(825) Changes of chemical potential in concentrated solutions of certain salts. R. E. Gibson and L. H. Adams. J. Am. Chem. Soc. 55, 2679-2695. 1933.

In the course of a general program of the study of the effect of high pressure on equilibria in binary systems it was found necessary to obtain data on the change of the chemical potentials of salts in concentrated aqueous solutions.

With the aid of a static apparatus of modified design, the relative vapor pressure lowerings of concentrated solutions of lithium chloride, ammonium nitrate, potassium thiocyanate and sodium sulfate were measured at room temperature. Various empirical equations expressing the relative vapor pressures of the solutions in terms of the concentration were examined and

it was found that for these salts, equations expressing $\log \frac{p}{p_0 X_1'}$ as a function of X_1' , where p is the vapor pressure of the solution, p_0 that of pure water, and X_1' is the mole fraction of the water calculated on the assumption that the salt is completely ionized, were the simplest and fitted the data most accurately. By means of these equations the difference between the chemical potential of either component in a solution of a given concentration and the chemical potential of the same component in a solution of any other concentration may be readily calculated. The convenience of the activity coefficient of the solvent, $\frac{p}{p_0 X_1'}$, whose logarithm is directly proportional to the chemical potential difference between solvent in the solution and solvent in an ideal solution of the same concentration, both as to ease of computation and applicability over the whole range of concentration is emphasized.

(826) Zur Hauynformel. (Eine Erwiderung.) Tom. F. W. Barth. Centralblatt Mineral. Geol. 1933 A, pp. 316-318.

From his X-ray studies of the minerals of the sodalite family, the author was able to establish the true chemical formula of the mineral hauyne (see No. 806 in this Report). This result was, however, afterward questioned by Machatschki. In the present paper it is shown that Machatschki's criticism is unfounded and is due to an inadequate knowledge of the symmetry properties of the space group isomorphous with hauyne.

(827) Pneumatolytic processes in the formation of minerals and ores. Clarence N. Fenner. Reprinted from *Ore deposits of the Western States*, Chap. III, Pt. I, pp. 58-106. 1933. Am. Inst. Min. Met. Eng., New York.

It is generally accepted by geologists that most ore deposits have derived their metallic minerals from igneous magmas. In some manner, small amounts of metallic elements, originally dispersed through large quantities of magma, have been concentrated to a high degree in veins and similar deposits. The process of concentration might be supposed to involve either the retention of the metallic elements in a small residual solution left by the crystallization of the greater part of the silicate material of the magma, or their removal from the magma by volatile gases of the sort known to be given off.

Both processes have been commonly recognized as operative, but probably greater importance has ordinarily been attached to the residual solutions.

In the present paper these matters are discussed in detail. The chief purpose is to trace out the manner in which gases may be evolved and residual solutions formed from magmas, their different behavior and composition, and the results they may be expected to accomplish, especially in the collection, transportation, and deposition of ores, but also, to some extent, in the deposition and transformation of other minerals. This involves the consideration of a number of physical and chemical properties of gases and liquids under the conditions prevailing in magmas and in adjacent wall rocks. These matters are discussed in direct relationship with the evidence contributed by the deposits themselves.

The evidence seems to indicate that though residual solutions may be important in certain types of deposit, the agents best adapted in most

cases to effect primary separation of metallic material from the magma and to transport it outward into the surrounding rocks are the acid gaseous emanations; that as these move into cooler regions they become condensed to aqueous solutions in which the ingredients react among themselves and with the wall rocks, and that the metallic ores are ultimately deposited by alkaline hydrothermal solutions thus generated, possibly augmented by attenuated residual solutions. The formation of ore deposits may often be the result of a somewhat complicated history, in which metallic compounds, extracted primarily by gases, are deposited by them, and later are picked up, transported and redeposited by aqueous solutions.

(828) The broader story of magmatic differentiation, briefly told. N. L. Bowen. Reprinted from *Ore deposits of the Western States*, Chap. III, Pt. II, pp. 106-128. 1933. Am. Inst. Min. Met. Eng., New York.

The differentiation of igneous magmas follows a course basic to salic largely as a result of fractional crystallization. In the salic types there is, therefore, an enrichment of all substances of the original magmas that share with the salic ingredients the property of forming low-melting combinations and associations. Some of these substances have this property to a superlative degree and may be called hyperfusibles. They are principally water, sulphur, chlorine, fluorine, boron and a number of others. As the salic magmas themselves crystallize, an increased concentration of the hyperfusibles in the residual liquid results. The trend is toward alkaline aqueous solutions, but with slow crystallization under heavy load the materials of these residues may be completely consumed in the formation of crystalline compounds which carry water, chlorine, boron, sulphur, fluorine, etc. Under less deep-seated conditions the residual liquid of crystallizing salic magmas frequently boils and a fractional-distillation column is set up in the interstices and fractures of the intrusive and its surroundings. This action results in the formation of a distillate which is an acid aqueous solution and it is such acid solutions that are probably the principal ore bringers. The solutions deposit their load as a result of reaction with the rocks through which they are forced as a consequence of the formation of vapor at the boiling source. They thus become neutral and finally alkaline, which is the eventual fate of hot waters in contact with rock minerals. Unless they are completely consumed in the formation of crystalline minerals (hydrous and the like) the regenerated alkaline solutions may approach the surface and, mingling with waters of the meteoric circulation, give rise to hot springs. In the less common case where the intrusive lies at very shallow depth, the distillate may reach the surface directly in the form of acid gases or occasionally acid waters.

(829) Notes on the X-ray diffraction patterns of mullite. E. Posnjak and J. W. Greig. J. Am. Ceram. Soc. 16, 569-583. 1933

A wide range of artificial alumina silica products has been examined by the X-ray powder method. In each case in which the pattern has been sufficiently clear to permit a decision, the pattern has been that of mullite, not that of sillimanite. The examination included a number of preparations made from clay minerals and clays at 1000°.

Mullite crystals containing alumina or the oxides of iron or titanium in solid solution give diffraction patterns in which the lines are slightly displaced toward the origin with respect to the corresponding lines in the diffraction pattern of the standard mullite ($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$).

Mullite crystals, freed by HF treatment from the matrix in which they grew, often give diffraction patterns in which the intensities of certain lines are strikingly different from normal. This is due to the orientation of the minute elongated crystals when mounted for photographing.

Finally, two recent papers proposing special names for certain similar materials are discussed and, on the basis of published data and the evidence presented here, these proposals are found to be unwarranted.

(830) The system, CaO-FeO-SiO_2 . N. L. Bowen, J. F. Schairer, and E. Posnjak. *Am. J. Sci.* 26, 193-284. 1933.

The method of investigation and the general importance of this system to petrology and metallurgy have been discussed in the Annual Report of the Director of the Geophysical Laboratory for 1931-1932, pp. 69-74. The completed results show that there are three ternary compounds, $\text{CaFeSi}_2\text{O}_6$ (hedenbergite, $2\text{CaO} \cdot \text{FeO} \cdot 2\text{SiO}_2$ (iron-akermanite) and CaFeSiO_4 . Only the last of these is stable at temperatures where liquid is formed in any of the mixtures. The others are stable only at low temperatures, hedenbergite below 965° and iron-akermanite below 775° .

The outstanding feature of the system is the occurrence of solid solution series, the most important of which are the two metasilicate series and an orthosilicate series.

The one metasilicate series is wollastonitic and extends from pure wollastonite (CaSiO_3) to 76 per cent FeSiO_3 . The other metasilicate series is hedenbergitic and extends from hedenbergite ($\text{CaFeSi}_2\text{O}_6$) to 80 per cent FeSiO_3 . The hedenbergitic solid solutions are stable only at low temperatures and are transformed at 940° - 980° to wollastonitic solid solutions.

Wollastonite solid solutions and Ca-Fe olivines occur together in equilibrium with some liquids of the system. The courses of crystallization of such mixtures are of much interest and are discussed in detail.

The optical properties of the crystalline phases have been measured and the variation of optical properties with composition in the solid solution series are shown in diagrams.

The X-ray diffraction patterns of members of the solid solution series have been obtained and are reproduced in the paper.

The bearing of the results upon the occurrence and composition of natural minerals is discussed, among them wollastonite, hedenbergite, larnite, fayalite, melilites and incidentally bustamite and johannsenite.

The significance of the thermal determinations in connection with the problems of slags is pointed out.

(831) Bavenite: Symmetry, unit cell. C. J. Ksanda and H. E. Merwin. *Am. Mineral.* 18, 341-344. 1933.

The symmetry of bavenite, $9\text{SiO}_2 \cdot \text{Al}_2\text{O}_3 \cdot \text{BeO} \cdot 4\text{CaO} \cdot \text{H}_2\text{O}$, has been definitely established by means of X-ray analysis and detailed optical study, thus correcting existing discrepancies in the literature. Bavenite is orthorhombic with an axial ratio, $a : b : c = 0.839 : 1 : 0.429$; unit cell dimensions, $a_0 = 9.67 \text{ \AA}$, $b_0 = 11.53 \text{ \AA}$, $c_0 = 4.95 \text{ \AA}$, referable to the simple orthorhombic lattice type, Γ_0 and is isomorphous with one of the space groups V^1 , $V^1_{h_2}$, or C^1_{2v} . The unit cell of bavenite contains one chemical molecule, and the density is 2.74_5 .

- (832) The electrical properties of glass. J. T. Littleton and G. W. Morey. John Wiley and Sons, New York, x + 184 pp. 1933.

This is the third in a series of monographs issued under the auspices of the Committee on Electrical Insulation, National Research Council. It is primarily intended as a reference book for laboratory workers interested in electrical measurements and dielectric theory. After a general discussion of the composition and properties of glass, the electrical properties are considered in detail and the pertinent literature is critically reviewed. A chapter is devoted to the electrical conductivity, both volume and surface conductivity being considered. The dielectric constant, the dielectric loss and the dielectric strength are treated in separate chapters, with special attention paid to their applications in electrical engineering.

- (833) Annual Report for this year.

- (834) An occurrence of iso-orthoclase in Virginia. Tom. F. W. Barth. Am. Mineral. 18, 478-479. 1933.

The optical properties of an iso-orthoclase occurring in a granitic gneiss in Northern Virginia have been determined.

Iso-orthoclase is a very rare variety of potash feldspar and has been observed previously only once. In contrast with all other potash feldspars, it exhibits a positive axial angle.

DIVISION OF HISTORICAL RESEARCH¹

A. V. KIDDER, CHAIRMAN

The Division of Historical Research comprises three Sections. The Section of Aboriginal American History concerns itself with studies relating to the rise of native civilization in the New World, its two principal fields being the Maya area in Mexico and Central America and the Pueblo area of southwestern United States. The Section of United States History conducts research upon the growth of Western European institutions in the Americas. The Section of the History of Science strives to bring together and to make available for interpretation the at present widely scattered and uncoördinated data which bear upon the acquirement and transmission of ordered knowledge.

SECTION OF ABORIGINAL AMERICAN HISTORY

As has been stated in previous reports, the present major effort of the Section is the attempt to develop a many-sided attack upon the historical problems of those parts of Mexico and Central America which, in pre-Columbian times, were the seat of the Maya civilization.

Carnegie Institution's first work in the Maya field was purely archaeological. Through exploration, and subsequently by excavation, studies were made of the distribution of Maya remains, and information was gathered regarding the nature of Maya culture at various periods. Progress of the research brought increasing realization of the importance of the role played by the Maya in building up aboriginal civilization in Middle America; and it also became obvious that the career of the Maya, were it sufficiently well understood, could be counted upon to provide valuable materials for the comparative study of civilization as a social-evolutionary process. But at the same time it was evident that to be of maximum usefulness for Middle American culture history and particularly for broader comparative purposes, our knowledge of the Maya must be much more comprehensive than we could hope to make it by archaeological means alone. For, as was stressed in the above-mentioned reports, the spade of the excavator can recover only factual data, and the interpretation of those data, in terms of the factors motivating and directing human action, can only be accomplished in the light of information as to the physical environment in which the Maya lived, as to their racial and mental make-up, as to their recent history and present social practices. With none of these problems is the archaeologist fitted to deal. So assistance was solicited from workers in many non-archaeological fields; and there has developed a program of investigation amounting to a general scientific survey of the Maya area.

Archaeological work and research in documentary history are going forward under the auspices of this Division; studies on physical anthropology are being prosecuted by the Institution's Department of Genetics; the food supply of the modern Maya and its effect upon basal metabolism are studied by the Nutrition Laboratory; cooperation with University of Chicago per-

¹ Address: Room 909, Tower Building, Washington, D. C.

mits work on linguistics and social anthropology; with the School of Public Health of Harvard University upon tropical medicine; with Clark University and University of Florida upon geography; with University of Michigan upon botany and zoology; with Duke University upon the biology of the inland waters of Yucatan.

During the year under review, notable progress has been made along many lines. At Chichen Itzá the program of excavation and repair of outstandingly important structures has been advanced by completion of work upon the Monjas, the most complex and architecturally the most instructive building in the city. An expedition into Campeche resulted in discovery of several new sites, as well as in closing the gap which has hitherto existed between the territory explored from the north and that reached from the south. At Uaxactun the investigation of the so-called "Palace" was continued; and various smaller structures yielded materials for the ceramic studies which are proving so valuable for reconstruction of the cultural history of the Old Empire Maya. The ethnological survey of Yucatan has been forwarded by observations upon modern life in Merida, the capital; in Dzitas, a large provincial town; and in the primitive communities in the forests of the former Territory of Quintana Roo. Anthropometric record of the development of Maya children has continued in certain villages near Chichen Itzá. There was begun a botanical survey of the grasslands of the Department of the Peten in northern Guatemala, a by-product of which was the finding of two large ruined cities, hitherto unknown; and, during the summer of 1932, a party investigated biological conditions in the *cenotes*, or natural wells, of Yucatan. Archive work in Spain and study of native Maya literature continued. The history of certain outstanding Maya families has been traced.

The above, and certain smaller but no less important, researches are reported upon in the body of this report. The mere listing of so considerable a group of activities implies the gathering of great amounts of information as to the past and present life of the Maya; and as to the environments, both physical and social, in which they have pursued their career. All this work, much of it carried on under great hardship and no little menace to health; all the toilsome accumulation of facts; all the expenditure of energy and funds, has been undertaken in order to find out how and why the Maya raised themselves from savagery to civilization, how and why that civilization fell, and what has brought about the conditions under which the Maya exist today. Could such knowledge even partially be attained, a highly significant contribution would be made to our understanding of that baffling creature, man. For the more we learn of his past, the more closely we analyze his history throughout time and across the continents, the more clearly can it be seen that in spite of the multiplicity of blindly fortuitous circumstances which have shunted him in this or that direction, which have brought some groups to dominance and others to obliteration; that in spite of all this, man's destiny has been shaped by the possession of certain attributes, or potentialities, or urges, or whatever one chooses to call them, which have resulted in fundamental similarity of development among all peoples. So the story of such a group as the Maya, who have run the full gamut of success and vicissitude, can not fail to be of deep significance for

the synthesis of human history which must some day be attempted. However, and this is the crux of the whole matter, no amount of fact-gathering will by itself tell that, or any other, story. The raw data must not only be collected, they must also be correlated in such a way as to bring insight into the workings of those infinitely complex concatenations of exterior circumstance and inherent human qualities which have always directed and will ever continue to direct the course of history.

The task of correlation and interpretation is manifestly of a far higher magnitude of difficulty than the accumulation of materials. It may, indeed, well be doubted whether it is possible to perceive the nature and to evaluate the action of the forces which have governed the career of any ancient people. But if the attempt be not at least envisaged, archæology becomes mere antiquarianism. This is so self-evident that its statement here would be unnecessary, were it not for the fact that our survey is a deliberately planned experiment, undertaken with the express purpose of determining whether such correlations and such interpretations are possible; whether, in short, archæological studies can sufficiently be illuminated and vivified to render them productive of valid historical conclusions.

Results can not, in any case, be quickly achieved. Merely to assemble the requisite mass of raw data will require long effort. Much time and large funds will be needed for the many necessary investigations. But it is not possible to begin too soon to look forward to the ultimate goal. Every worker can produce materials which will be more serviceable for his own purposes, and of much greater usefulness for the eventual synthesis, if he sees his activities in their relation to the whole project and keeps in mind the broader ends for which they are undertaken. To do this the members of the survey must know what is going on; the success of the program depends, indeed, upon close touch being kept between all participants. Current research can of course be followed in the Year Book and by reading the conclusions, at least, of all publications of the survey. Personal contacts are of even greater importance. By word of mouth one can learn most effectively what one's colleagues are thinking and deducing, what they really see in their work, what they are planning for the future. Through such intercourse comes the sympathetic understanding of others' problems, the appreciation of their difficulties, and the willingness to give as well as to get, which alone can develop the team-play so essential for the success of our most difficult undertaking.

ARCHÆOLOGICAL RESEARCH

CHICHEN ITZA

The work at Chichen Itzá, under direction of Dr. Morley, consisted of excavations by Mr. John S. Bolles at the Monjas; repair of the Temple of the Phalli by Mr. Gustav Stromsvik; and continuation of Mr. H. B. Roberts' ceramic studies. Mr. John O'Neill and Mr. Stromsvik also remapped the nearby ruins of Yaxuná; and Sr. Alfonso Villa made the first traverse of the ancient highway which connects the cities of Yaxuná and Cobá. The Institution's station at Chichen Itzá served, as usual, as headquarters for collaborating investigators and as base for the Campeche expedition.

EXCAVATIONS AT THE MONJAS—J. S. BOLLES

The Casa de las Monjas (House of the Nuns), so called because of its cell-like chambers, is one of the best-preserved structures at Chichen; archæologically it is probably the most important building in the city. Hence its investigation, begun in 1932 and carried to virtual completion during the current year, demanded very thorough planning and most careful execution, in order that the search for scientific information should not lead to loss of esthetic values. This was a particularly difficult task, because the Monjas owes its significance to the fact that it underwent many rebuildings and almost countless alterations: removal or covering up of earlier elements, addition of wings, changes in plan, elevation and decoration; all of which have resulted in producing a veritable puzzle in massive yet treacherously insecure masonry. It was naturally desired to recover as much information as possible regarding the nature and sequence of the various structural increments; but some of these had been so nearly obliterated that there remained only the slightest traces of their former presence, and others were deeply buried under later construction. To have begun at the outside and to have studied and removed the increments one by one would, of course, have been a relatively simple procedure. The Monjas, however, is among the finest of Maya temples. It was therefore imperative that excavation should not mar in any way the great beauty of its present semiruin condition. Furthermore, our knowledge of Maya architecture is not yet sufficiently complete to guarantee that we will not overlook phenomena of importance to future students. So no part of the building could safely be removed; and Mr. Bolles and his associates were accordingly forced to exercise the greatest ingenuity in trenching, pitting and tunneling. How well their work was done can only become apparent when it is fully published. The Monjas, as they have left it, gives no indication that it has been so deeply and so thoroughly probed.

Such a report as this does not permit the inclusion of the many drawings and photographs necessary to make clear even the general structural history of the building; to say nothing of its many highly significant details. A brief summary of the work must therefore suffice.

The investigation had two phases: excavation and study of the building complex, and its repair and consolidation. Replacement of fallen parts was undertaken only where necessary for the preservation of standing elements and then only when there was definite evidence to justify such procedure. There were times when repairs had to wait until certain excavations were completed; excavations were often delayed for repairs.

Search was made for evidence bearing on the nature, extent and interrelation of the terraces underlying and surrounding the building proper. This required a great number of relatively shallow trenches and pits, all of which were ultimately refilled. They resulted in defining the limits of certain terraces; others, largely or wholly removed during alterations to the complex, could only partially be run out. It was a very difficult matter to hold the exterior trenching within bounds, as there was constant temptation to follow interesting and possibly important leads, which, however, were-

certain to involve the excavators in problems of other nearby buildings not immediately pertinent to study of the Monjas.

All Maya temples were erected upon basal platforms. The site of the Monjas bore several successive temples, each one larger and higher-set than its predecessor. Hence there now exists a series of basal platforms, one within the other, some of which can be examined at places where they have been exposed by the caving of later masonry. To secure information as to others and to study the buried faces of all, it was necessary to tunnel, both vertically and horizontally, through many meters of loosely piled rock fill, a costly and often dangerous procedure. Data, however, were recovered upon the size and method of construction of the platforms; it was also determined that none of the earlier temples is still extant.

Concurrently with the architectural study of the latest building with its annexes and wings, there was carried forward the work of repair and repointing. From their footings to their crowning friezes of stone-mosaic masks the platforms were carefully gone over, and every room of the building was checked from floor to vault peak and roof. The broken west end was given a new facing of rough stone, as nearly as possible like the old end that was continuing to break away in great sections. This type of work will delay for years the collapse of the Monjas. The Iglesia and the Southeast Annex were also given the same thorough going over. Throughout the work, every effort was made to preserve the charm of the Monjas as a ruined Maya edifice and to hold intact all the work of the original builders. Floor levels and wall lines were carefully saved, for no matter how careful the excavation or how minute the observations, something is bound to be overlooked or something destroyed that may later be of infinite value as more is known of the Maya and their construction methods.

The great two-flight stairway, which gives access to the upper buildings, was found to be in exceedingly bad condition. Removal of débris west of the lower flight showed that insecure footings had led to the development of a crack so serious as to threaten collapse of the entire west face of the stairway. This necessitated very extensive repair, including the introduction of sound new footings and the binding of the crack by means of concealed iron rails with bent-down ends. The undertaking was a hazardous one, as hundreds of tons of stone were in imminent danger of falling. A section of the stairs did, indeed, give way, painfully injuring Mr. Bolles and narrowly missing killing him. Photographs taken before the repair began permitted exact replacement of the steps that had come down. The second-story stairs were also jeopardized by the weakened condition of the supporting platform and had to be removed and rebuilt along with the dangerous section of platform. Again, photographs were used to insure accurate resetting of all stones in their former positions.

One of the most important aspects of the investigation was the making, by Mr. R. T. Smith, of measured drawings of the many masks which embellish the Monjas. These masks, huge and grotesque conventionalized faces, are, in essence, mosaics of cut stone, the dozens of individual pieces tenoned into a masonry backing. Such masks formed one of the principal decorative elements of Maya architecture. They varied both locally and chronologically and so constitute a potentially most useful criterion for the

classification of buildings. Mr. Smith's drawings set a standard of accuracy heretofore unattained. Their analysis will form the basis for the careful comparative study of masks which will eventually have to be made.

Mr. F. P. Parris, of the University of Pennsylvania Piedras Negras expedition, joined Mr. Bolles toward the close of the season. His drawings of the seven carved panels of the ball court south of the Monjas show every detail of design and every variation of curve. No more accurate rendition of low-relief sculpture could be made.

TEMPLE OF THE PHALLI—GUSTAV STROMSVIK

In 1926 investigations were made by G. C. Vaillant and J. E. Thompson at the Group of the Initial Series in "Old Chichen." The Temple of the Initial Series, the Temple of the Little Heads and the Temple of the Atlantean Columns were completely excavated.¹ Exploratory work was also done at the nearby Temple of the Phalli, which indicated that a thorough examination of that building and its many annexes would constitute a project too large to be undertaken at that time. During the years between 1926 and 1933 it was hoped to reopen operations at this very important temple. But as it is now evident that renewal of activity in Old Chichen must still further be postponed, it was decided to fill the old excavations and to carry out certain repairs which would guarantee the structure against deterioration. These tasks were accomplished during the past field season. The complex of courts and colonnades was cleared of unworked stone, sculptured elements were assembled, columns were re-erected, and walls were repaired and capped. The capping of walls unprotected by roofs is accomplished in the following manner: All faced wallstones, which threaten to lose their hold, are numbered and taken down. Then the root-riven mortar of the wall's core is worked out until solid ancient masonry is exposed. The core is built anew with fresh materials and the original veneer of faced stones is replaced, each block going back to its exact former position. Finally, a capping of spalls and mortar is laid along the wall-top. This is made high in the center to facilitate drainage and to prevent lodgment of earth in which vegetation might gain a footing with consequent damage by the wedging action of roots.

The roofed chambers of the Temple of the Phalli were cleared of debris; walls were strengthened where necessary; and new wooden lintels, replacing ancient lintels now rotted away, were introduced over certain doorways and reinforced by hidden steel rails. The roof of the building also received such attention as was necessary to prevent leakage with consequent damage to the cores of the walls. This important and interesting structure is now in such condition that, if it be kept clear of bushes and trees, it will stand for many years.

CERAMIC RESEARCH—H. B. ROBERTS

The Section's study of the pottery of Yucatan was inaugurated in 1926 by G. C. Vaillant, who established a preliminary classification of the wares found at Chichen Itzá. The investigation, continued in 1930 and

¹ See Year Book No. 25, 270-273.

1932 by Mr. H. B. Roberts, comprised thorough examination of the large sherd collections taken in previous years from excavations in various temples at Chichen Itzá; stratigraphic tests in several refuse deposits in the city; and organization with Mr. H. B. Pollock, of the Architectural-Ceramic Survey, which, in 1932, resulted in accumulation of stratigraphic data from Coba, Sabacche, Labna and Yaxuna. Review of the situation at the close of 1932 indicated that one more field season could be counted upon to complete the local ceramic picture and to furnish the evidence necessary for the relative dating of the more important buildings. It also appeared desirable to finish all contemplated work at Chichen Itzá before undertaking further activities in other localities, for it was evident that full ceramic data should as quickly as possible be made available for the use of those members of the staff who were engaged upon other archaeological problems of the site. Furthermore, it was felt that a well-rounded knowledge of Chichen pottery would permit new evidence accruing from extension of the Architectural-Ceramic survey more readily to be fitted into its proper place in the general ceramic scheme. Mr. Roberts therefore decided to devote himself exclusively to Chichen Itzá in 1933.

During the field season (ending June 10) the sorting and classification of all ceramic material obtained from the structures excavated by the Chichen Itzá Project were completed. The pottery found in 1932 and 1933 by Mr. Bolles in his study of the Monjas and associated structures was examined and classified. This material is archaeologically the best documented series from the city and covers the longest period in time of any collection studied. It will prove very valuable for making the final determination of the chronological sequence of Chichen Itzá wares.

The sherds taken by Mr. Ruppert from the Mercado-Southeast Colon-nade group in 1932 were classified and studied in relation to those from the large refuse deposit near that structure examined by Mr. Roberts during the same year. The pottery series obtained from these two locations correlate very well and provide an excellent ceramic picture of the period during which the buildings were under construction and in use.

During the course of the season some thirty test pits, fairly well distributed over the city, were dug in areas likely to reveal stratified refuse. Sixteen of the pits were enlarged into trenches, located in the following groups: north of the terrace of the Group of the Initial Series, north of the terrace of the Principal Group of the Southwest, east of the terrace of the Group of the Hieroglyphic Jambs, east of the Group of the Sculptured Jambs, north of the House of the Deer and Red House, and Colorado, *bajo* north of the Temple of the Three Lintels, and *bajo* west of the Guest House. While the material from these trenches has not been sufficiently studied to allow definite and final statements, it seems certain that we now have a fair sample of the ceramic make-up of Chichen Itzá and that three main ceramic periods may be discerned:

- I. Pre-Mexican period with pottery similar to that of the Labna-Puk region.
- II. Period of Mexican occupation.
- III. A period following the era of Mexican domination, characterized by the return of certain earlier Chichen Maya forms.

The close relative dating of the sherds from individual buildings will be on the basis of sub-periods which have not as yet been clearly worked out.

It is believed that we are now in possession of data adequate for preparation of the ceramic history of Chichen Itzá which Mr. Roberts is at present engaged in writing. Further work would certainly add many details, but, until new and improved methods for the study of pottery have been developed, such work does not seem justified.

In addition to the materials from Chichen Itzá, Mr. Roberts examined the sherds collected by Mr. Ruppert in southern Campeche. Although the collection is too small to warrant confident conclusions, it appears that the wares fall into groups which may roughly be correlated with certain architectural changes noted by the Campeche Expedition.

SURVEY OF YAXUNÁ—JOHN P. O'NEILL

The ruins of Yaxuná, a short distance to the south of Chichen Itzá, are archæologically important because their architecture differs strongly from that of Chichen, because they are allied ceramically to the cities of the Puk and to Cobá, and because they form the apparent terminus of the great ancient highway running westward from Cobá. In preparation for possible future excavations, Mr. O'Neill and Mr. Stromsvik devoted a week in early February to mapping the site.

Yaxuná is reached from Chichen Itzá in seven hours on horseback by a trail which runs from Piste to the ruined hacienda of Xcolup and thence through the village of Yaxuná; or in six hours via Old Chichen and Yulá. The present Maya village of Yaxuná lies about one kilometer west of the ruins.

The survey began by a preliminary examination from the top of a high, centrally located pyramid. It and all other structures rise from a flat plain covered with a low, sparse growth of bush. This permitted the establishment, by triangulation, of reference points upon all important platforms or pyramids, from which traverse lines were run wherever necessary. Measurements were made almost entirely by stadia readings, the tape being used only in the rare instances where walls were discernible, or for determining short distances upon mounds.

The site is roughly diamond shaped, the short axis measuring about 0.5 kilometer, and the long axis (north by northeast) a little less than 1 kilometer. This layout includes a group to the south not before reported. A cenote near the ruins was found to be 300 meters, N 53 W, from the northwest corner of the platform which supports the northernmost pyramids and the only standing structure of the site. A large artificial mound is said by the natives to stand one kilometer north of this cenote.

On a clear day, when the sun is near or past the meridian, the Castillo at Chichen can be seen from the high central pyramid of Yaxuná. Under especially favorable conditions some of the other structures at Chichen are visible by the aid of the theodolite. Observations for bearing and distance were therefore made, which show Yaxuná to be 17.8 kilometers, S 32°00' W (true) from the Castillo. Referring to the recorded position of the Castillo at Chichen, the latitude of the Ruins of Yaxuná is — 8.3', or 20°32.6' N; and the longitude, +5'30", or 88°39'40" W.

SURVEY OF THE COBÁ-YAXUNÁ HIGHWAY—A. VILLA

The long *sacbe*, or raised highway, which originates at Cobá, has been believed to join that city with the ruins of Yaxuná, some 60 miles to the west. Both ends of the road had been examined, and Captain Bennett recently traced it well eastward from Cobá, but no complete traverse had been made. This was done by Mr. Alfonso Villa during the past winter. Mr. Villa, with a force of twelve Maya Indians, left Yaxuná on February 27, and devoted three weeks to cutting his way the entire length of the *sacbe*, through to Cobá, making a measured survey and recording features of archæological interest encountered *en route*. He reports that the road is from 30 to 34 feet in width and that it is raised to a height of from 2 to 8 feet. It was built by erecting retaining walls of large, roughly faced limestone blocks and filling between them with rough stones, which became progressively smaller toward the surface. Its actual roadbed was finished with a smooth coating of lime plaster. For 43 miles eastward from Yaxuná the road runs almost perfectly straight; in the last 19½ miles before reaching Cobá it makes five slight changes of direction. At intervals there are mounds built close to the highway; and near Cobá are several monuments bearing badly eroded hieroglyphs. At 21 miles from Yaxuná was discovered a limestone cylinder 13 feet long, 2¼ feet in diameter, and about 5 tons in weight, which, it is thought, may have served as a roadroller.

EXPLORATIONS IN CAMPECHE—KARL RUPPERT

As result of the exploration and study of Calakmul in 1932¹ and reports of other sites in the same general region, an expedition spent the months of March, April and May in the exploration of south-central Campeche. Mr. Karl Ruppert, archæologist, was in charge; Mr. John H. Denison jr. served as epigrapher; Mr. John O'Neill, as surveyor. The field of work was reached from Chichen Itzá via Merida, Campeche, Canasayab, La Gloria and Central Buenfil, which was made the base of supplies.

Messrs. Denison and O'Neill made a preliminary trip to Calakmul to take observations for latitude and longitude (N. 18° 8.7'; W. 89° 50' 21"). On March 10 the entire expedition left Central Buenfil for the ruins of La Muñeca, which were reached at 2.30 the same afternoon. La Muñeca is a dry camp. Anyone visiting the site, except during the rainy season, should, Mr. Ruppert reports, be prepared to haul water from two to six leagues.

La Muñeca was visited in 1932 by Messrs. Ruppert and J. S. Bolles but, due to lack of time and illness, only a sketch map of the site and a preliminary examination of the stelæ and buildings were made. The latitude and longitude of the site are N. 18° 14.7' and W. 89° 37' 00". The ruins lie on two low ridges, which have their long axes north and south. Thus the city is divided into two well-defined sections, of which the westernmost contained the highest mounds and all the stelæ. Nineteen stelæ were found, of which 8 are carved, 7 carrying Initial Series dates. The earliest and latest dates for the city are 9.13.0.0.0 and 10.3.0.0.0, respectively.

The next objective was Placeres, an abandoned chicle station 7 leagues to the east, which served as base for the expedition for seven days while trails were opened and the nearby areas to the south, west and north were ex-

¹ See Year Book No. 31, 95-96.

plored. Leaving part of the supplies and equipment at Placeres, the expedition left on March 26 for a three-weeks trip to the north and west. Stops were made at the sites of Noche Buena, Rio Bec and La Hormiguero.

Noche Buena is an extensive site, a hard 6 hours ride north of Placeres. The buildings have almost entirely fallen. Only in a few cases are sections of wall or arch still in position. The study of the buildings showed the incorporation of lateral wings in the ground plan in several instances. No stelæ were found.

March 30 to April 7 was spent at Rio Bec. This city was discovered by R. E. Merwin of the Peabody Museum some 20 years ago. Merwin's Group F and G were the only ones examined by the present expedition, attention having been confined to the area west of these groups. The site was not recognized as Rio Bec until after Mr. Ruppert's return from the field, when the latitudes and longitudes were checked. They are N. $18^{\circ} 20.5'$ and W. $89^{\circ} 22' 4''$, respectively. Merwin's groups to the east of F, the nearest of which is $11\frac{1}{2}$ miles, were not seen. The principal structure in the western area, Structure D, Group I, with its lateral towers, was recognized as being of the Rio Bec type. The masonry is the finest found, being made up of small, carefully worked stone the size of bricks. The low platforms supporting buildings have the same measurements in plan as the buildings themselves. These platforms are either plain or ornamented with colonnettes. Excavations in front of doorways did not show steps giving down from the platforms. Stucco and stone decoration covering the façades or as inset panels of geometric design was used in the ornamentation of the buildings. A type of construction not seen at other sites visited is a low rectangular platform supporting a building which extends around three sides of the platform. In the center of the open side, or sometimes in the middle of the platform, is a small masonry altar-like mound.

Hormiguero, located at latitude N. $18^{\circ} 24.0'$ and longitude W. $89^{\circ} 38' 35''$ was next visited (April 9 to 14). It is much smaller than Rio Bec, but is similar in style of architecture. The use of lateral towers was noted on two structures. The principal building has a length of 47 meters, a width of 10 meters and contains eight rooms. In one room the ceiling was intact. The central doorway of the south façade is still supported by wooden lintels. Stucco decoration on the same façade is in a good state of preservation. Great lateral towers, with stairways as decoration only, are used as at Rio Bec.

Leaving Hormiguero on May 14 the party started southward, retracing its steps to Placeres. Here it was necessary to lay over for four days while the men opened trails, and muleteers made a trip to Central Buenfil for supplies. Staying one night at the aguada of Delicia, the abandoned chicle camp of Alta Mira was reached May 20. On the way in to Alta Mira (N. $17^{\circ} 56.7'$, W. $89^{\circ} 31' 53''$) there are many mounds to be seen along the trail. Returning the next day to examine these mounds and the area lying between them and the camp, a small but carefully laid out city was found. There were 16 stelæ, of which half showed some trace of sculpture. No dates, however, were secured. Only small sections of standing walls were noted. One room, perhaps the central room of a three-chambered structure, has a portion of the arch still intact. The building carried a roof comb.

April 25 the party moved to the abandoned chicle camp of Villa Hermosa (N. $17^{\circ} 55.8'$ and W. $89^{\circ} 40' 35''$). While waiting for the men to open trails and locate water, two days were spent exploring the many low mounds to the northeast, some of which were $1\frac{1}{2}$ to 2 leagues from Villa Hermosa.

The next objective was to find Nohochna, reported by C. L. Lundell as a new site in 1931. The drying up of the aguada forced the party to evacuate Villa Hermosa before the scouts had located water near Nohochna. This necessitated a detour by the way of the aguada of Monterey. Once at Nohochna, Mr. Ruppert recognized the site as Naachtun, discovered in 1922 by Dr. Morley. The party remained here from May 1 to May 12, during which time a new and more inclusive map was made. The latitude and longitude are N. $17^{\circ} 47.7'$ and W. $89^{\circ} 44' 22''$, respectively. Of the 45 stelæ at Naachtun, 18 were found by Morley in 1922, 8 by Lundell in 1931, and 19 by the present expedition. Only 24 show carving. The earliest Initial Series reads 9.3.10.0.0, the latest surely readable date is 9.16.0.0.0. Some of the standing buildings are of particular interest in that they resemble Maler's Temples I, II, and IV at Tikal, having three rooms, one behind the other, decorative extensions on the rear exterior wall and a niche in either end wall.

Mirador, the westernmost site visited (N. $17^{\circ} 40'$; W. $89^{\circ} 50'$), is perhaps that seen by Percy Madeira during his aerial survey in 1931.¹ It contains the largest and highest mounds that were encountered. There are at least 9 lofty pyramids, the largest and highest of which supports 7 good-sized mounds, of which the largest rises not less than 20 meters above the top of the great pyramid. As there was no water, it was only possible to spend one day exploring. No standing buildings were found. A small piece of sculpture, perhaps from a stela, was noted reused in the facing of a low terrace.

The final ruin visited (May 21) was Tres Marias, northeast of the chicle station of Rio Disempeño. Tres Marias is a dry camp so that only a hasty examination of the ruins could be made. The site is small and has no standing buildings or stelæ. There is one plain round altar.

Between the dry aguada of Tres Marias and the ruins great numbers of small mounds were noted. They usually appear on the crest of hills. The mounds, outlined by large unworked stones, are irregular in shape and vary in size from 3 to 4 meters in greatest dimension. In height they rise 1 to 2 meters. They are often arranged around courts and may well represent dwelling house sites.

May 28 the expedition returned to Chichen Itzá, having been in the field exactly three months.

The expedition accomplished a preliminary survey of the area in southeastern Campeche from Central Buenfil to the east, north and south. Mr. Ruppert believes that since many groups of small mounds were encountered, perhaps representing dwelling house sites, there may well be large religious or civic centers associated therewith which still remain undiscovered in this section of the vast tropical forest. The area should be entered at some time when chicle operations are under way, so that the chicle gatherers may

¹ The Museum Journal, University of Pennsylvania Museum, vol. XXII, No. 2, p. 121, June 1931.

be questioned and rumors or reports of sites may be pursued. The work of the *chicleros* takes them off the trails in all directions through the dense bush, so that they cover the country much more thoroughly than an archaeological expedition is able to do.

EXCAVATIONS AT UAXACTUN—A. L. AND R. E. SMITH

The eighth season's work at Uaxactun, the Old Empire city in northern Peten, Guatemala, was carried on under the direction of Mr. A. Ledyard Smith with the assistance of Mr. Robert E. Smith and Mr. Francis Richardson. A. L. Smith and Richardson arrived in camp on March 5. Robert Smith remained in Guatemala City, studying the pottery recovered in 1932, until March 31, when he joined the expedition. The party was at Uaxactun until June 6, at which time they left for Guatemala City to study and write up the material acquired during the season.

During the first weeks in the field, activities were limited to the excavation, in A Group, of Structure A-V, a fine example of the so-called "Palace," or complex multi-chambered building, a type which, in the Old Empire, has hitherto been very little investigated. The investigation of A-V was started at the end of 1931 and continued in 1932. At the end of the latter season a good deal of light had been thrown on the question of the purpose of this sort of structure. It had also become evident that it would yield a true architectural stratigraphy, which could be correlated with ceramic finds. The program for 1933 was therefore to complete the excavation of the outer structure of A-V as far as possible, and to begin work on the earlier buildings buried underneath, in order to collect samples of pottery from below floors of various periods and so obtain a ceramic as well as an architectural stratification. Pottery recovered was then to be compared to that of E Group (upon which the ceramic periods of Uaxactun had already been established); it was also to be checked against the pottery obtained from a well-stratified rubbish heap, prolific in sherds, which was discovered in 1932 near the edge of the plaza south of the Palace.

On his arrival, Robert Smith started work on the rubbish heap mentioned above. He enlarged his 1932 pit and isolated a column of refuse for stratigraphic study. In addition to this he partially excavated Temple A-XV, to secure further information on pyramids and their superstructures, and sank exploratory pits in and about B Group in search of more middens.

Richardson cleared two adjoining chultuns, or jar-shaped chambers cut into the limestone bedrock, at the base of A-XV, each of which yielded a skeleton in very poor state of preservation. He also made a plane table map of A Group showing all elevations, the detail of excavated structures, the probable position of unexcavated walls, and the extent of the mounds covering unexcavated buildings.

A-V, the Palace in A Group, rests on a low, roughly rectangular platform of masonry some 280 feet long and 240 feet wide. Its greatest height, as it stands today, is nearly 50 feet. This building consists in the main of four courts, all but one of which are surrounded by rooms, whose vaulted roofs have in most instances fallen in. The exception is the East Court, which has rooms on but three sides, the east or remaining side consisting of a long, low platform from whose top an unusually broad stairway leads

down into the East Plaza. The courts lie at different levels, access from one to another being gained by stairways. The Main Court and the South Court with their adjoining rooms were cleared in 1932. Pits were dug through their floors, revealing earlier constructions which had been buried in the process of enlarging the Palace.

During the 1933 field season, excavation of the outer structure of A-V was almost completed. All the upper rooms, the East Court and the rooms overlooking it have been uncovered, as well as a portion of the North Court. So far, fifty-five rooms of the outer structure have been cleared. These rooms vary greatly in length, width, height and function. Three distinct types of room construction have been found in stratigraphical position. Differences in walls and vaults control, to a great extent, the width of the rooms, the earliest being much narrower than the latest. Early walls and vaults are built of flat uncut stones laid horizontally and held together by the abundant use of cement, the whole roughly plastered. Late construction is of well-cut stones veneered vertically against a hearting; the vaults consist of nicely fitted beveled stones approaching in shape the specialized vault stones of northern Yucatan; all masonry is smoothly plastered. Continued excavation beneath the floors brought to light a buried pyramid under the Main Court and, under the South Court, a series of buried rooms which in turn had been built over a terrace and against an earlier room opening thereupon. Several hitherto unexplored parts of the outer structure have been penetrated and earlier construction exposed. At the present stage of the investigation, it appears that the Palace must originally have constituted a small group of independent buildings, which were joined together and added to until they became a single great unit.

The excavations yielded a great number of artifacts, sherds, and figurines which throw much light upon the function of the Palace, and upon the appearance and dress of its inhabitants. Most of the material so far found comes from above the floors of the courts and rooms, but whenever these floors have been penetrated different types and shapes have occurred. Animal and human bones were found in abundance above the floors, usually in sheltered corners. The human bones, as well as those of animals, show signs of cutting. Many of the human long bones had their extremities removed, and the parts of the shaft still connected to the extremities are cut longitudinally. Such specimens were confined to the latest deposits; hence, if they indicate cannibalism, it seems only to have been practiced after the general break-up of the Old Empire.

Two new stelæ were discovered in the Palace, one carved and one plain. The latter was standing in position, but had been covered by later construction, the former lay in the rubble under the floor of one of the latest rooms. This stela, which is only a fragment, bears the date 9.5.0.0.0. Seven burials were found, some under the floors of the courts, some in the masonry of benches in rooms, others above floor-level with no protection except a few rough stones placed around them. Both sexes and all ages were represented. In every instance the skeleton was flexed. There were very few mortuary offerings. Most of the bones were in a good state of preservation.

One of the most interesting finds in A-V was a fresco which once covered the whole back wall of a room. It shows traces of red and orange, but for

the most part is in black lines. Unfortunately, more than half of it had been destroyed by roots and the fall of stones, but from what remains it is clear that a scene of action was depicted. Figures in full costume carrying spears and standards and others dressed only in loin cloths face each other from either end. In the lower right-hand corner is a double-headed serpent with fish swimming into its gaping mouths; and in the corresponding position at the opposite end is a temple in outline. The latter is of exceptional interest, for it shows a complete roof comb. This is our only evidence as to the nature of this crowning feature of the Uaxactun temples.

To sum up: The work on the Palace during 1933 resulted in recovery of a definite architectural stratification, which shows a gradual and logical development of wall and vault construction. The pottery so far taken from below floors of various periods correlates with the building sequence; it also fits perfectly into the pottery sequence previously established, and with that of the pottery from the stratified rubbish heap near A-XV. The sherds from below the earliest rooms belong to Ceramic Period II. From this and other evidence the existence of the Palace must have been an extremely long one. Mr. A. L. Smith believes that this building had a dual function, residential and religious, and that the latter was secondary to the former. Shrines with their altars and stelæ indicate ceremonialism, but all other rooms show signs of having been lived in. The walls of many are blackened by cooking-fires and on their floors is débris of occupation in the form of animal bones, fragments of pottery, and broken implements. These remains can not all be attributed to people clinging to the site after its general abandonment, or to later wandering tribes, because similar evidences occur in some of the earliest buried rooms. That there was a post-Old Empire occupation is, however, certain. Rooms whose vaults and outer walls had fallen were, in some instances, roughly blocked off, rather than properly repaired; refuse sometimes lies upon débris of disintegration; burials were made above floors; there is suspicion of cannibalism. All this is characteristic of a degenerate people, but who they were is still a problem.

R. E. Smith conducted excavations in Pyramid B-VIII to determine whether or not the burial chamber discovered by him in 1932¹ was constructed before or after the erection of the pyramid. It was found that the burial chamber was erected on the platform of a low pyramid hewn from the solid limestone bedrock. The mortuary chamber formed the core of the additional terraces built up from this natural mound.

Pyramid Temple A-XV was also investigated. Architecturally it corresponded to the earliest member of the Pyramid A-I complex. Its superstructure had been a one-room masonry temple, with a single doorway to the south. The walls of the temple were made of small, roughly cut stones set in thickly spalled mortar and heavily coated with plaster (an early architectural feature at Uaxactun). Directly south of the doorway and resting on the frontal platform was a hollow altar(?) filled with shrew bones. Burned potsherds covered the floor of the temple room, the altar and the frontal platform adjacent to the doorway. About three feet below the temple floor two small adjoining crypts were uncovered. One yielded

¹ See Year Book No. 31, 97.

a cache of obsidians and eccentrically shaped flints; the other a poorly preserved baby burial. The plastered walls of both crypts were draped with what appeared to be charred rope, of which several fragmentary specimens were saved. A second cache of eccentrically shaped flints and obsidians, together with a deer antler, lay above the crypts.

An undated Stela (numbered A-15), broken in two places, was discovered facing the center of the south stairway. Its butt penetrated about 15 inches below the floor at the pyramid base and was associated with a cache containing four eccentric flints, one eccentric obsidian, one conch shell, four jade beads, and five lancet-like obsidian blades. In line with Stela A-15, but about 7 feet farther south, was a large, round unsculptured altar supported by three stones.

In addition to work on the above pyramids, R. E. Smith carried out extremely important investigations in refuse deposits. Success in study of ceramics at any given site is dependent upon finding an abundance of stratified material. At Uaxactun, an analysis of the sherds found between plaza floors in E Group, within multiple pyramidal construction in Pyramid A-I complex, and associated with various house mounds, had led to a preliminary chronological classification. Not until 1932, however, was a well-stratified and prolific rubbish heap discovered just off the plaza south of Palace A-V. A trench was dug through this midden from south to north and in 1933 a column 10 feet square was excavated layer by layer. Although the thirty-odd thousand potsherds removed from the column have not yet been thoroughly examined, R. E. Smith's study has already showed that polychrome wares existed in each of the six strata; that certain vessel shapes disappeared and new ones took their place; and that three or possibly four sequent periods of pottery making were represented. Finely decorated wares and especially painted pieces were plentiful and excellently preserved. This very valuable material renders it for the first time possible to work out in detail the gradual development of decorative design at Uaxactun. Beside pottery, Pit 14 column yielded bones, both human and animal, implements of bone, flint and obsidian; and beads of shell and jade.

The existence of the stratified midden in A Group suggested that careful searching elsewhere might locate other deposits which would serve to correlate ceramically the other temple groups of the city. As experience has shown that such deposits may often be found in low-lying areas near buildings, five pits were sunk in the environs of B Group, but without success. It would seem logical to believe that each group had its own dump. Absence of middens, as in B Group, might, in R. E. Smith's opinion, be due to periodical removal of debris for use as filling material in building operations. He also points out that if this practice was general, it might be dangerous to establish chronological sequences on the basis of pottery taken from the interior of substructures.

EXCAVATIONS AT QUIRIGUA—O. G. RICKETSON JR.

The greater part of the year was spent by Dr. and Mrs. Ricketson in Guatemala City, completing their report upon Uaxactun, in which Mr. Ricketson describes the excavations and Mrs. Ricketson treats the pottery and other artifacts. In the spring of 1933 Dr. Ricketson spent two weeks

at the ruins of Quirigua in the lower Motagua Valley to report upon the feasibility and probable expenses of making the ruins into an accessible and properly protected national park; to determine, if possible, subplaza conditions, especially with regard to stratification, either natural or man-made, by which successive periods of occupancy could be distinguished; and to collect sherds from successive strata, if any, for comparison with the ceramic sequence obtained at Uaxactun.

In order to determine whether the ruins of Quirigua merited a more or less intensive archæological examination, especially from a ceramic standpoint, 8 pits were sunk within the ruins proper—5 in the Main Plaza, 1 in the Ceremonial Plaza and 2 in the Temple Plaza at the extreme south. Every pit in the plazas proper disclosed natural river cobbles as pavement underlying silt accumulated since the monuments were erected. The average depth of this silt is 0.96 meter. Five of the six pits struck clay at an average depth of 2.70 meters beneath the present surface and a sixth, Pit 2, pierced a clayey sand which gradually merged into a sandy clay at about 3 meters. Pits 3 and 8 exposed butts of stelæ, both of which were erected in rock ballast—about the only method possible for the erection of large and tall monoliths in such soft soil as composes the plaza. The deposits contained a disappointingly small number of potsherds, most of which came from below or in the topmost pavement. They are being studied by Mrs. Ricketson.

ARCHÆOLOGY OF THE GUATEMALA HIGHLANDS—S. K. LOTHROP

Dr. S. K. Lothrop, who by courtesy of the Peabody Museum was able to carry on investigations in Guatemala during the spring under the auspices of Carnegie Institution, continued his study of Highlands pottery. He examined and very fully photographed the fine collection of Padre I. Rossbach at Santo Tomas Chichicastenango and visited certain sites from which the vessels emanated. During the year Dr. Lothrop also completed a report, now in press, upon his excavations of 1932 near Santiago Atitlan.

SITES NEAR LAKE PETEN—C. L. LUNDELL

While engaged in botanical studies in the savanna region near Lake Peten,¹ Mr. Lundell, who in 1931 discovered the city of Calakmul, found several new archæological sites, the largest of which lies in heavy forest on the border of the savanna five miles west of La Libertad, near the small settlement of Polol.

The Polol ruins consist of a central group of mounds covering approximately half a square mile. This area was thoroughly explored and mapped. There are no standing buildings. The main plaza is bounded on the south by a great terraced pyramid bearing fallen temple structures. Its dimensions are: base, 318 by 390 feet; summit platform, 100 by 105 feet; height (measured up the very steep slope), 170 feet. In the plaza are 15 stelæ, of which at least 6 are sculptured. All save one have fallen and broken. The largest (No. 10) is 7 feet 5 inches wide, 2 feet 9 inches thick, and almost 12 feet long. It bears glyphs on the two sides, a large human figure on the

¹ For botanical report see p. 107.

face. Another (No. 3) has glyphs on sides and back, a figure on the face. From Mr. Lundell's photographs and drawings, Dr. Morley has deciphered Initial Series dates which indicate that Polol was occupied during the Great Period of the Old Empire, at least from 9.15.0.0.0 (Stela 10) to 9.18.0.0.0 (Stela 1).

A second site was found in open country five miles south of La Libertad, south and east of the aviation field in the San Francisco, Santa Teresa and Chica savannas. Exploration revealed numerous low mounds, terraces, stone paved courts, stone foundations and floors of round and rectangular structures, extending over an area about two miles long by a mile wide. There are apparently no stelæ. Mr. Lundell named the ruins Chakantun (*chakan* = savanna; *tun* = stone).

At the ruins of Tayasal on the shores of Lake Peten,¹ there was discovered, on the plastered surface of a terrace partially cleared by native lime-burners, a very interesting series of incised non-realistic pictographs: whorls, crosses and meandering lines.

During a delay on the outward trip, explorations were made among the ruins on the islands at the west end of Lake Yaxha. On the island of Topexte, previously investigated by Maler, 8 stelæ and 3 altars were encountered. Of these, Stelæ 1 and 2 are sculptured. The most interesting structure on the island is a well-preserved terraced pyramid on the summit of which there stands a columned temple. Two adjacent islands were visited and, on a third, two additional sculptured and inscribed stelæ were found. These, designated Stelæ 9 and 10, have not hitherto been reported. The ruins on Topexte were mapped and the stelæ on both islands were photographed.

HIEROGLYPHIC RESEARCH—S. G. MORLEY, J. E. THOMPSON

Dr. Morley devoted such time as he could spare from administrative duties to completion of his monograph "The Inscriptions of Peten," second of the compendious treatises in which he plans to cover the entire field of Maya monumental epigraphy. The first, "The Inscriptions of Copan," appeared in 1920; the third will include all sites not considered in the first two. It is believed that the Peten volumes will go to press in 1934. The preparation of the many maps, plans, drawings and photographic plates has required periodic visits by Dr. Morley to Washington, where, under the able and painstaking supervision of Mr. T. R. Johnson, this great body of material is being prepared for the lithographers and engravers.

Mr. J. Eric Thompson, on leave from the Field Museum of Natural History, spent half a year in hieroglyphic research under auspices of the Carnegie Institution. His work consisted of an examination of the notes left by the late Research Associate of the Institution, Dr. John E. Teeple, at the time of his death, and of the mathematical testing of glyphs whose meanings are unknown.

Doctor Teeple's material, kindly loaned to Carnegie Institution by Mrs. J. E. Teeple, proved to be almost entirely calculations without explanatory notes, the great majority evidently having been made for his publication,

¹ See Year Books Nos. 20-22.

"Maya Astronomy." Almost all the residue dealt with the application of the determinant theory to Maya dates at various cities. Unfortunately, it would appear that the subject-matter of the publication which Doctor Teeple had in view at the time of his death was never committed to writing and, except for a few notes, has perished with him. It is unnecessary to emphasize the great loss to science that this entails.

Doctor Teeple's material was incorporated into a general survey of the application of his determinant theory to each city.¹ The incomplete results suggest the feasibility of a correlation between high mathematical ability and low artistic ability in certain cities. For instance, in accuracy of determinants Naranjo ranks very high, yet the art of this city was always provincial and stiff. On the other hand at Yaxchilan, where Maya art reached its apogee, the determinant theory largely breaks down. Where the level of art is high, there is a tendency to frequent mistakes in the inscriptions and indifferent calculations. At Copan, however, where the art was definitely masculine, as opposed to the somewhat effeminate art of the cities of the Usumacinta Valley, accuracy and a high artistic standard go hand in hand. Results of the work upon determinants will probably throw light on the relations between different cities. For example, in the early period before 9.15.0.0.0 the determinants at Palenque and Copan are in pretty close agreement, calculating the interval from Cycle 13 at about two days more than Gregorian. At 9.15.0.0.0 Copan started to calculate at one or two days less than Gregorian; Palenque had, apparently, ceased to erect epigraphic monuments; while Naranjo as early as 9.12.0.0.0 was reaching the same accuracy as Gregorian, but in the later dates around 9.17.0.0.0 had turned to the old Palenque-Copan formula.

In the mathematical testing some twenty glyphs were chosen. In each case every known example from the monuments was noted, together with its position in the tropical year, distance in days from the mythical start of the calendar, and year-bearer under which it fell. The distances in days between all examples of each glyph were then calculated and the results submitted to every mathematical combination which it was thought the Maya might have employed. These included all astronomical figures, such as revolutions of the planets, but not the sidereal revolutions, which it would seem almost incredible that the Maya could have realized. The year-bearers under which each example fell were also examined for indications of any ritualistic grouping.

The results were disappointing. One group led to the hope that it might comprise seasonal glyphs, possibly gods ruling over thirteen divisions of the tropical year, forming a kind of zodiac, but the evidence is not conclusive. Nevertheless this method holds out the best hope of learning the meanings of unknown glyphs; and its findings will be universally accepted since they can be shown to be mathematically correct. A publication incorporating the determinant material is now in course of preparation. In it will be embodied a discussion of the Venus glyphs.

¹A determinant is any date which the Maya appear to have used to declare what addition should be made to the Long Count in order to bring any specified date in the 365-day year into the same relation with the tropical year as it was believed to have possessed at the mythical start of the calendar at 13.0.0.0.0, 4 Ahau 8 Cumhu.

SOUTHWESTERN RESEARCH

Both Mr. E. H. Morris and the Chairman have spent the greater part of the year in preparing publications. Mr. Morris is working up materials, gathered during many years of excavation, for a monograph upon the archæology of the extremely important area lying north of the San Juan River in northwestern New Mexico and southwestern Colorado. He took the field, however, for a few weeks in the autumn of 1932, carrying out, in cooperation with the National Park Service, certain much-needed repairs upon the remarkable tower of the Mummy Cave ruin in Canyon del Muerto, Arizona. He also excavated several early Pueblo sites east of the Chuska Mountains in search of charred beams for use by Dr. A. E. Douglass in dendro-chronological studies.

The Chairman has been at work upon the second volume of a monograph upon the pottery of the pueblo of Pecos, in north-central New Mexico.

COLLATERAL RESEARCHES ¹LINGUISTIC INVESTIGATIONS, BY MANUAL J. ANDRADE ²

The first half of the period under consideration was devoted to the preparation of a description of the Maya language spoken in Yucatan and northern British Honduras. The completion of this work was postponed in order to concentrate on the analysis of the Huastec material collected in 1930, which had to be undertaken at this time in view of the fact that we intend to return to the Huastec region in the summer of 1933. Such preparatory work will enable us to enter the field with certain problems definitely formulated. It may thus be possible to concentrate our efforts on the collection of a sufficient amount of data to elucidate the most difficult aspects of this language.

So far as we may judge from the material in our possession, a thorough study of Huastec should throw considerable light on the history of the languages of the Maya stock. At present it is not safe to draw conclusions regarding the relation of Huastec to any other specific particular group of the Maya stock. Its structure is definitely Maya, but its vocabulary seems to contain many foreign elements, a study of which will doubtless indicate with what peoples this isolated member of the Maya family has been in more or less intimate contact. This will eventually necessitate a knowledge of such neighboring languages as Totonacan and Otomi. A study of Totonacan will be of particular interest, since it has been suspected by some writers, although on scanty evidence, that it may be related to the Maya stock. However, the isolation of foreign elements in Huastec can not be undertaken with any degree of confidence until we can determine the phonetic and morphologic correspondences between this language and its cognates. Some words which at first sight appear to be foreign may prove to be Maya. Such instances have already been observed in the limited comparative work which has been done.

¹ For accounts of the archive work of F. V. Scholes and that upon the Books of Chilam Balam by Ralph Roys, see report of the Section of United States History, pp. 114 and 119.

² Dr. Andrade's research is a joint undertaking of the Department of Anthropology of University of Chicago and Carnegie Institution of Washington.

In the summer and autumn of 1933, we shall for the first time use in the field the electrical apparatus designed for our future work in the Maya linguistic project. On that field trip we shall have an opportunity to try what may prove to be a more efficient technique of recording connected discourse than the usual method of dictation employed heretofore. Considerable time has been devoted to the perfection of the apparatus and to repeated experiments in conditions approximating those encountered in the field. It remains to be seen whether the equipment can be taken to the field without impairing some of its necessarily delicate mechanism.

SOCIOLOGICAL STUDY, BY ROBERT REDFIELD¹

The culture of the present-day inhabitants of Yucatan is not Maya, in the sense that it does not represent the ways of life of the pre-Columbian inhabitants of the peninsula. The archæologist, but not the ethnologist, deals with this ancient and extinct culture. There is, therefore, no Maya ethnology, strictly speaking, as there is a Maya archæology. Ethnology deals with the cultures of living peoples, and in Yucatan this living culture is neither Maya nor Spanish. It is not even quite fair to the facts to say that it is part Maya and part Spanish. When two cultures are brought together, the new culture is not the sum of so much of the one and so much of the other, but a new third thing which is an original growth rather than a mere mixture. When we say that certain elements in this present-day culture are "Maya"—such as rain-gods associated with the four directions, bark-beer and bee-hives—we mean only that their presence in the contemporary culture is historically due to continuity with Indian tradition rather than Spanish; but each of these traits and every other, whether Indian or Spanish in origin, has been re-formed and re-defined in terms of the new traits and the other changes that have taken place in Yucatecan life in four hundred years. The contact between Spaniard and Indian resulted in a new culture—the Yucatecan folk culture. Looking at the facts, one gets the feeling that most of the changes and re-definitions of meaning took place in the first few generations after the Conquest, and that this Yucatecan culture was not long in forming. Certainly today it is very widely and fairly uniformly distributed. And today it is often difficult to say to what extent contemporary customs are derived from a European tradition or from the Indian heritage. Shall we say, for example, that the custom of bleeding for illness is Indian or is European in origin, in view of the fact that both European and pre-Columbian Maya practiced such a custom? And if we say it is Indian in origin in the village and European in the city, then what is its origin in the intermediate town? Such problems do not easily lend themselves to solution.

The project upon which we are engaged turns aside from these problems of historical analysis, and takes the Yucatecan folk culture as its basic datum. Our task is double: first to describe this culture and then to study the changes that are taking place in it as a result of the impingement upon it of influences from the city and the wider world. For, in varying degrees,

¹ Dr. Redfield's work on the Maya is made possible by the cooperation of the Department of Anthropology of University of Chicago, which grants him, through courtesy of its Chairman, Dr. Fay-Cooper Cole, periodic leave to take the field.

the communities of Yucatan are undergoing modification due to increasing contact and mobility. Schools, moving pictures, social and political propaganda and economic exploitation tend steadily to modernize Yucatan. The plan of study proposes the simultaneous investigation of three or more communities, affected in varying amounts by these modernizing influences, and then the comparison of these communities. Such a comparison, it is assumed, will amount to a summary description of the process of civilization, or modernization, in Yucatan. We aim to describe, in the form of a concrete instance, the transition from primitive (folk) society to civilized (urban) society. Moreover, as this is a change that has taken place and is taking place in many parts of the world, it is hoped that by comparing this Yucatecan instance with others elsewhere, a more general (and in this sense more scientific) description of the process of civilization can ultimately be realized.¹

The study of this basic folk culture was initiated in 1930-31, when Alfonso Villa and I began work in Chan Kom, a village just south of Chichen Itzá. In the following year Villa undertook trips of ethnological reconnaissance among the still more isolated villages of the forest hinterland to the south, and Dr. Asael T. Hansen began the study of Merida, the one city of the peninsula. The year just ending (1933) saw the work in Merida carried forward by Dr. Hansen, while Mrs. Redfield and I added a fourth community to the series of comparable units by making a short study of Dzitas, a town of mixed bloods, situated on the railroad immediately north of Chichen. Mr. Villa made one extensive trip into (what was until recently called) Quintana Roo, and two shorter trips. He further strengthened his position among the suspicious Indians of this region, and secured some ethnological data, but the poverty of the natives there made it impossible for him to remain for more than a few days in his rôle of merchant, and indicated the advisability of postponing intensive work among them until chicle exploitation should be resumed. Accordingly, Mr. Villa spent six weeks making a survey of the Cobá-Yaxuná sacbe (see p. 89) and devoted the remainder of the field season to beginning a study of the Shaman-Priests or h-mens of Yucatan, both of the rôle of these important personages in the village life and of the more or less esoteric specialized lore which they possess and transmit to their successors. In this he was greatly aided by the acquaintance he already had with several of these h-mens and by his knowledge of the Maya language. He visited seven or eight of the most renowned h-mens of the Valladolid region and began the collection of data which will make known to us the pagan religion as it is understood and practiced by these specialists.

Dr. Hansen, assisted by Mrs. Hansen, continued the study of Merida, remaining in that field of work during the autumn of 1932 and the first eight months of 1933. The Hansens took up their residence in a different part of the city, on its western edge, and a study they made of the block in which they dwelt, compared with a similar study made the previous year in the *barrio* of Santa Ana, and with a shorter study made this year at their direction of a neighborhood in the south side of Merida, enabled them to know something of the range of regional differences in culture and

¹ See Year Book No. 31, 111.

of local homogeneity within the city. These differences turn out to be fairly small. Indeed, as the work progresses we are struck with the essential uniformity of the basic culture. Traits found first in Chan Kom turn out to be present as well among the lowest classes in the city, even though these city-dwellers are from old urban families with much white blood and with Spanish surnames. The ideas of disease and its treatment, the practices at childbirth—even such apparently Indian customs as the little ritual known as *hetz mek*, wherein the infant is handed objects supposed to assure his success in later life—occur in the city. But the linkages and emphases of the customs are very different as city is compared with village; and it is the definition of these differences that constitutes the description of the civilization process to which I have already referred as the goal of these investigations.

The Hansens' materials are particularly rich in respect to the topics of sickness and its cure and of the family. Here enough has been learned to permit of a statement with some assurance as to the essential attitudes and institutions, and of the variations in respect of these elements of culture as one social class in Merida is compared with another. Furthermore, enough historical material, for the recent period, has been obtained, either from informants or from documentary sources, to add a temporal dimension to the Merida study: Dr. Hansen is preparing an historical account of recent changes in kinship and the family. In this investigation, the relation between technical changes (capitalistic exploitation of henequen; wealth and foreign travel) and familial attitudes becomes apparent. Dr. Hansen's investigation of sickness and its treatment in Merida also begins to reveal how the folk practices, especially those carried on by the village h-men, have become assimilated with and modified by elements introduced from other sources, such as medieval European magical handbooks, and a spiritualistic cult introduced by the sophisticated but taken over and re-interpreted by the masses.

During the first month of this field season I was engaged in a revision of a manuscript prepared in 1932 and embodying the materials collected by Villa and me in Chan Kom. In this revision I was assisted by Don Eustaquio Ceme of that village, who spent the period with me in Dzitas. The last month of the season I employed in a visit of general reconnaissance in the highlands of Guatemala, with a view to the possible extension of the ethnological work into that field. The remainder of the winter and spring months Mrs. Redfield and I devoted to a brief study of Dzitas, as a town intermediate on the scale of modernization between Chan Kom and Merida. Here the social and cultural range was explored by a preliminary house-to-house canvass to determine the name, occupation, language and costume—whether *mestizo* or *catrin* (folk costume or “store clothes”)—of the occupants. This census guided us to a fair sampling of the community in our subsequent more intimate dealing with informants and in our direct participation in domestic activities, and also led to an understanding of the interesting situation with regard to class and race in Dzitas. Here assimilation and amalgamation have proceeded so far that—setting aside the more sophisticated viewpoint of a few teachers and officials recently come from the city—all the people, whether predominantly Indian

or predominantly European in blood, and whether Indian or Spanish in surname, participate in a single culture. Even in ceremonies held in the fields to the pagan agricultural deities, mixed bloods of Spanish surname take part along with those more apparently Indian. In spite of this, however, there endure the vestiges of a class system based on race, as socially defined: persons with Spanish surnames, no matter what their color or occupation, are *vecinos*; while those with Indian surnames are *indios*. The mobility of very recent years is bringing the *indio* into specialized occupation and into residence near the center of town, and the Revolution gave him the offices of municipal government; nevertheless the older *vecino*—culturally much the same as the *indio*—tends to resent this encroachment upon what two generations ago was recognized, by numerous social usages, as his superior status and he thinks of the *indio* as a socially lowly class. Thus in Yucatan the class distinction between mixed-blood and Indian outlived the cultural differences between them; but this distinction, as a definite class distinction, has vanished in the city and is disappearing in Dzitas. The situation contrasts with that in Guatemala, where the difference between *ladino* (corresponding with *vecino*) and *indio* (*indígena*) is exceedingly sharp, and where it is a difference both of culture and of class. In Guatemala, contact between Indian and Spaniard made two cultures; in Yucatan it has made one. This presents for investigation a problem in the field of race relations.

During the season, Dr. Hansen kept in frequent communication with us, so that a beginning was made with the comparative treatment of the materials gathered separately in the three communities of Merida, Dzitas and Chan Kom. Taking the chief institutions one by one, we began a tabular summary of the characteristics and functions of each. In this way differences between one community and another became sharply apparent; the summary comparisons became, in effect, hypotheses for further testing. The statement of this preliminary comparison must find a place elsewhere than in these pages,¹ but among the general differences as one moves from village to town and then to city are: increasing cultural heterogeneity; increasing division of labor and the development of secular specialists at the expense of sacred and traditional functionaries; breakdown of a close familial organization appropriately supported by sacred ritual; decreasing influence of religious sanctions upon conduct; conversion of the annual fiesta from a sacred rite to a mere holiday or commercial opportunity; and the changing quality of the agricultural rites, which are acts of true piety in the village, mere magical acts of safeguard in the town, and disappear, with agriculture itself, in the city, the deities to whom in the village these rites are addressed becoming mere evil or mischievous spirits, or characters in entertaining tales. Unexpected to me was the apparent increase of black magic as one goes from the village to the city. The applicability of this generalization with respect to other communities must be tested, and the reason for it is to be sought. It may be connected with the spread of foreign magic into Yucatan by way of the city, and it may also be an aspect of the increasing mobility and insecurity, in the city environment, of

¹ *Culture changes in Yucatan*, paper read June 22, 1932, before Section H, American Association for the Advancement of Science.

a people still primitive in their mode of thinking. And this double possibility in turn reminds us of the wisdom of using both historical and sociological approach in order to get a full understanding of a social situation.

FAMILY HISTORIES IN YUCATAN, BY RALPH ROYS

In addition to reading the proof of the *Book of Chilam Balam of Chumayel*,¹ I have made a preliminary survey of a large number of Maya texts from the Spanish archives at Seville which have been discovered and photographed by Mr. F. V. Scholes. These consist chiefly of letters from Maya chiefs to the King of Spain and complaints by the natives of Yucatan of abuses committed by certain Spanish Governors. These promise to be of the greatest value to the study of the linguistics and the history of Yucatan.

Much of the year has been spent in work connected with the collection of Xiu family documents now in the Peabody Museum and known as the *Crónica de Oxtutzcab*. The general character of these papers has already been outlined in a previous report.² This work has involved a comparison of the material with the published and manuscript sources for the history of Yucatan. Unpublished documents have been found in the libraries of Tulane University and the University of Pennsylvania which parallel and amplify the ethnographical data occurring in the Xiu collection; these have also been edited and translated and will form a part of the Xiu publication.

The Xiu papers come to an end with the fall of the Spanish regime in Yucatan. They present an unbroken history of this famous family from about the year 1400 A. D. until 1817. This is a unique record, as no other aboriginal American family, not even those of the Montezumas or the Incas, can be traced in this manner. Accordingly, a field trip to Yucatan was made for the purpose of continuing the history of the Xiu down to the present time. The complete record of this family is of especial interest, for they flourished as rulers for at least five and a half centuries, were privileged nobles for the next two hundred and eighty years, and now for more than a century they have earned their bread by the sweat of their brow.

Other objects of this trip were a study of the extent of the former native states as outlined in the Sixteenth Century Maya land treaties and an examination of the parallels existing between the Books of Chilam Balam and the archæological remains in Yucatan.

In Yucatan a personal search of the Church and Municipal archives, supplemented by interviews with many members of the Xiu family, resulted in the acquisition of a large body of genealogical material. This is very complete for the descendants of the last noble head of the family, of whom one hundred and eleven persons, living or dead, were found in the sixth generation alone. Also practically all the living Xiu who could be located were traced back to ancestors listed in the 1817 patent of nobility, the last of the collection. The pedigrees obtained offer much that is of interest to students of genetics. The ages of mothers at the time of the birth of their oldest children should have a bearing on the theories of embryologists regarding puberty, adolescence and maturity. The material collected also furnishes information regarding size of families, child spacing, percentage

¹ Year Book No. 30, 157.

² Year Book No. 31, 123-124.

of illegitimate births, infant mortality and comparative ages at death. Causes of death were noted wherever possible. The direct descendants of the last noble head of the family have not done particularly well during their century of economic struggle, for they are less prosperous and show a higher rate of infant mortality than the collateral family groups which were the subjects of this study.

The ethnographical material is of especial value and its study was greatly aided by the field trip. Journeys were made along the borders of the ancient native kingdoms as indicated by the documents, and it was discovered that a strong feeling of sectionalism still exists and follows the lines of the old frontiers. Not only was this feeling reflected in the Maya land documents of the Colonial period, but it has persisted down to the present time. A considerable portion of the country traversed was practically depopulated for many years during the War of the Castes, the inhabitants having retired to more protected centers of population. Inquiries at the towns and hamlets on both sides of the line elicited the information that the present inhabitants had returned from their own side of the old frontier, stopping short at it and rarely penetrating the territory of what had been the neighboring state in pre-Columbian times. The Spaniards found Yucatan divided into a number of independent states, which were believed to have dated only from the fall of Mayapan in the middle of the Fifteenth Century A. D., but conditions suggest that a sectionalism, which has persisted in spite of almost four hundred years of political unity under foreign rule, must have required a much longer time for its development than the comparatively short period which elapsed from the destruction of Mayapan until the Spanish Conquest.

A search was made for the site of the ancient town of Cetelac, which is said by the Book of Chilam Balam of Chumayel to have been a depot for the collection of tribute at the time of the conquest of Chichen Itzá by Mayapan about the end of the Twelfth Century A. D. A place of this name was located only a kilometer from the ruins of Yaxuná, the western terminus of the famous causeway and closer to the ruined city than the town from which the latter takes its name.

A visit to Mayapan, the former capital of northern Yucatan, was of great interest. Mexican architectural features, such as triple doorways and serpent columns, correspond to the Maya tradition which associated the Nahuatl term, *tecpan* (government house), with this city. Although the mere use of columns does not necessarily imply a *tecpan*, the large number of columned structures at this site are of such a character as to indicate their resemblance to the council halls described by the Spanish conquerors on the highlands of Mexico. They are too numerous to have belonged only to the Mexican mercenaries stationed at Mayapan but correspond rather to the presence of the headchiefs of northern Yucatan, all of whom were said to have been obliged to reside at the capital and govern their own districts from a distance.

It is at Chichen Itzá, however, that we find the greatest number of analogies between the Books of Chilam Balam and the archæological remains; and these, strangely enough, are largely confined to the Mexican period of this city. It shows the strong influence exerted by this foreign culture upon

the native population, when we find these alien traditions still preserved in the Maya literature of the Spanish Colonial period, in spite of the hatred with which the Mexicans were regarded in Yucatan.

Some of the statues at Chichen Itzá amply justify the Maya reproaches that the Itzá were immodest and indecent. Here, too, are sculptures of the animals which symbolized the Toltec warrior orders, the four trees and birds of the creation story, the rattlesnake and the "house of skulls" (the Tzompantli), all of which figure in the Books of Chilam Balam.

The examination of the local archives, as well as interviews with a large number of the native population, afforded an opportunity to make a study of Maya family names and their distribution. Some are confined to certain localities, while others are widely spread over the entire country. The meanings of some of these names, which are those of mammals, birds, insects, trees and plants, suggest a former clan organization among the Maya. A few are Mexican, while others, difficult to translate, seem to correspond to the names of certain tribes or nations. The value of these names to the study of ethnology is apparent, and this material will be presented in an appendix to the Xiu Chronicle.

ANTHROPOMETRIC AND OTHER STUDIES, BY MORRIS STEGGERDA

With Mrs. Steggerda acting as recorder, I began this season's work at Chichen Itzá on January 31. This was our third year of work in Yucatan on the problem of growth in different racial groups. In the Maya growing series there are ninety-two boys and seventy-eight girls from the villages of Pisté, Chan Kom and Xocenpich. These children have now been measured for three successive years and it is planned to measure them annually until all have finally matured. Similar series of White and Negro children have been measured, with which these will be compared.

It has been our purpose from the beginning to analyze genetically as many families as possible in the towns in which we worked. From the first year we have plotted pedigrees of the families, showing their relationships and the number of children per fraternity, also stillbirths and miscarriages. We have determined the relationship in detail of every family in Pisté, several in Chan Kom and some in Xocenpich. At present we have forty-five pedigrees, representing some five hundred or more individuals; of this number fully two-thirds have been measured in detail, some of the children several times. Each season we measure additional members of the families, record any who have died, married, or moved away, and other like notes.

In order that the family study may be as detailed as possible and also possess sociological interest, we had made, with the cooperation of Dr. Morley, a map of Pisté showing all streets and houses. We then made a canvass of the town, and thus determined just who lived in each house and the purpose of the house (dwelling, storage, kitchen, laundry, apiary, etc.). In addition, we have taken for permanent record typical photographs of streets, houses and yards. Furthermore, we made this season a complete census of the town. This includes the number of adult males and females and children both living and dead for each fraternity, as well as the size of

each man's milpa (corn field), during the last two years, number of horses, cows, pigs, chickens, beehives, dogs and other animals.

Realizing the importance of the agronomic problem for all Maya studies, I wished to gather as accurate data as possible regarding soil deterioration under cultivation. We know in general that the Indians abandon their milpa after two successive years, and that the corn yield is about 50 per cent less the second year than it is the first. We accordingly selected a mecate (approximately 400 square yards) of typical land, bounded it with stones and took a sample of its soil for analysis. It is hoped that each year corn may be grown on this mecate and its soil annually analyzed in order to determine quantitatively the amount of deterioration and the percentage of loss in corn each year.

In addition to the above, there was made a study of the stature of the human figures carved upon the columns of the Temple of the Warriors, which indicated that while the sculptures are some shorter than living Maya, the range of distribution for stature is the same. This perhaps lends color to the theory that the figures are actual portraits of individuals. Another activity was the gathering of saliva samples from Pisté men for Dr. Weston A. Price of Cleveland, who is conducting researches upon the causes underlying dental caries. Mouth-casts were also made for Dr. Price.

Leaving Yucatan on March 4, we undertook a reconnaissance trip in the Highlands of Guatemala and in the Mexican state of Chiapas, with a view of determining the possibilities of those regions for an extension of the anthropometric and genetic studies already under way in Yucatan.

We were able to measure several adults, making approximately seventy-five observations on each subject. A few of the essential dimensions are given below to indicate their general characteristics:

	75 Quichés and Mames Guatemala	77 Yucatan Maya
Stature	153.2	155.1
Head length	183.7	180.4
Head breadth	143.9	153.7
Cephalic index	78.4	85.0
Bizygomatic width	137	143
Bigonial breadth	107	106

From these figures it will be seen that the two groups are of about the same stature and that the Yucatan Maya have shorter and broader heads and are thus more brachycephalic than the Highlanders. The Yucatecans also have broader faces.

We were impressed by the high percentage of goiter in the Highlands and by the absence of baldness which is so common among Yucatan Maya women. The Highland Maya are also more independent and seem more artistic than those of Yucatan. We have made some excellent contacts in Guatemala. We believe that the metabolism of these people should definitely be determined and also that further anthropometrical work should be done, so that a closer comparison can be made with the Maya of Yucatan.

BOTANICAL-HERPETOLOGICAL SURVEY, BY C. L. LUNDELL AND L. C. STUART

The biological survey of the Maya area under the joint auspices of University of Michigan and Carnegie Institution was forwarded by studies made between March 28 and June 12, 1933, in the savanna country near La Libertad, Department of the Peten, Guatemala. The expedition was in charge of Mr. C. L. Lundell, botanist; Dr. L. C. Stuart served as herpetologist. Its purpose was to explore the area and make a preliminary biological and geographical survey. There was collected a total of 2800 plants and more than 10,000 herbarium specimens, together with ecological data and information regarding vernacular names and native uses of the plants. Plant associations were carefully studied, and every collection was made according to habitat. All of the plant associations were photographed. Frequency indices were made to show the distribution of species in the various ecological areas. Dr. Stuart took soil samples from every area, and Mr. Lundell gathered geological data which will aid in defining the vegetational zones.

In spite of the fires which swept the bush and open areas, it was possible to obtain a representative collection of the dry-season flora of the western portion of the Peten savanna country. As this work represents the first extensive plant study made in the region, the collections are of great scientific interest. Many of the plants are new, and in some groups as many as 10 per cent are probably new species. Emphasis was placed on groups least known from the Maya area. Extensive collections were made of mosses, ferns and the epiphytes which include orchids and numerous species of the pineapple family. Some interesting new palms were found and adequate herbarium material was obtained, so that this group can be critically studied. Especial attention was given to trees, and some interesting new species were discovered.

The flora of the savanna country varies considerably from that of the Yucatan Peninsula. The area may be considered as the transition zone between the floras of Yucatan and the region to the south. The line where the Yucatan flora terminates may roughly be drawn across the base of the Peninsula from Laguna Perdida to Lake Peten and then to the Belize River in British Honduras.

The savanna country may be considered as a definite phytogeographical division. It is apparently the bed of a great ancient lake. The region consists of wide open areas of red clay of great depth broken by low ranges of forested limestone hills. As the open clay country is very fertile, it was probably cultivated extensively by the ancient Maya. This cultivation and the seasonal fires accompanying it may account for the present open savanna areas. The flora is essentially that of species adjusted to annual fires. Bush is encroaching in every direction, and if there should be a period of wet years without fire, there is every likelihood that the entire region would be reclaimed by forest. Studies were made of the forest species which appear to be reclaiming the open country.

The ethnobotanical work included a study of the food and fruit plants now found in central Peten. Many of these plants were important in the

economic life of the ancient Maya. Mr. Lundell's earlier studies on Maya agriculture and the milpa system were continued.

The herpetological work of Dr. L. C. Stuart, while successful from the standpoint of specimens and ecological data collected, was seriously hampered by the prolonged drouth and severe fires which swept the region. In the savanna area approximately 1100 specimens of reptiles and amphibians were secured. These were distributed as follows (figures are only approximations):

Group	Specimens	Genera	Species
Amphibians	490	9	15
Saurians	440	11	16(?)
Ophidians	75	19	22
Chelonians	95	4	6(?)
Crocodylians	2	1	1
Total	<u>1102</u>	<u>44</u>	<u>60(?)</u>

In addition to these specimens about 350 more were secured in British Honduras and en route to and from La Libertad, bringing the total of the herpetological collection to about 1500 specimens.

In working over the material, Mrs. Helen T. Gaige of the Museum of Zoology will pay particular attention to the amphibians, Mr. N. E. Hartweg of the same institution will study the turtles, while Dr. Stuart will devote his interests to the lizards and snakes and to the compilation of ecological data.

Although no intensive work on the collection has been done to date, a preliminary survey shows that the ranges of several species have been materially extended, that taxonomic conclusions must be altered in several cases when comparisons are made with this and material collected by the two previous expeditions, that a redefinition of several forms must be made and, possibly, the description of several new species. Material of other than taxonomic interest lies in observations made on breeding habits, time of activity and ecological relationships of the savanna and bush forms. For accomplishing these results the Museum of Zoology has been particularly fortunate in securing for comparison, through the courtesy of Miss Doris Cochran and Dr. Leonard Stejneger of the United States National Museum, material collected in Peten for that institution by the late Harry Malleis.

Future work in the same area is necessary if the entire herpetological fauna is to be known. This is due to the fact that barely three weeks were spent on the savannas after the rains had set in, and many of the wet season forms had not yet emerged when the expedition was forced to return.

BIOLOGICAL RESEARCH IN INLAND WATERS OF YUCATAN, BY A. S. PEARSE

Yucatan is a sheet of limestone which was raised out of the ocean in rather recent times. It has very little soil above the porous bed rock. The country is very flat, the greatest elevation being less than three hundred meters above sea-level. There are no rivers in Yucatan, but numerous cenotes, aguadas and caves exist. Along the coasts there are extensive brackish cienagas. At the base of the peninsula, beyond the city of Campeche, there are rivers. The most northern of those is the Rio Champoton.

The cenotes, aguadas and certain caverns in Yucatan are isolated aquatic habitats. Some of them, at least, have so existed for long periods of time and their faunas and floras are therefore of unusual biological interest, especially in relation to adaptation and evolution. Because of this and also because of the economic importance of these bodies of water, both in ancient and modern times, the Division invited Professor F. Gregory Hall of Duke University and Dr. Edwin P. Creaser of the University of Michigan, and A. S. Pearse to investigate the biology of the cenotes. During June, July and the early days of August 1932, 28 cenotes, 10 aguadas, 7 caves, 2 savannas, 2 localities on an extensive coastal cienaga, several pozos, one spring and a river in Campeche were studied. Dr. Creaser spent most of his time collecting and preserving fish, reptiles, insects, crustaceans and other animals for the Museum of Zoology, University of Michigan. Professor Hall studied the chemistry and temperature of every body of water examined. His determinations included oxygen, carbon dioxide, hydrogen-ion concentration, hardness, salinity, temperature and depth.

In the interior of Yucatan a cenote is usually an isolated body of very clear water with more or less precipitous walls, which at times may project as ledges above the water. Cenotes often have considerable depth and usually a clean sandy or rocky bottom. A cenote may have apparent connections with underground water and at times there is a slow current passing through. But a few cenotes appear to have no connection with underground water and are stagnant, turbid and thermally stratified, so that there is a difference of as much as 5° C. between bottom and top, and there is hydrogen sulphide in their deeper waters. In the neighborhood of Chichen Itzá, the surface of the water in cenotes stands about 20 meters below the surface of the ground. The depths of cenotes studied in that region varied between 8 (Ciruak) and 54 (Scan Yui) meters. At Merida, 35 kilometers from the coast, the water-level was about 5 meters below ground-level and the depth of the water was 3 to 7 meters.

The collections of animals from the aquatic habitats in Yucatan are now being studied, and therefore generalizations can not now be made, but some remarks concerning the findings may be of interest. Catfishes of the genus *Rhamdia* were found in all cenotes studied and in many of the caves. These will be classified by Dr. Carl L. Hubbs of the University of Michigan. They may, or may not, give light on the effects of prolonged isolation on animals. The parasites of the cenote fishes have been preserved and the study of them may also give some evidence as to the affinities of cenote animals. At times, cyclids and other fish were found in inland cenotes. These were perhaps introduced by man. Plankton was sometimes abundant in the open cenotes, but was very scanty in those with small openings. In caves cirolanid isopods, two or three species of blind shrimps and schizopods were found. Such animals suggest marine relationships. They were not found in cenotes, aguadas or rivers.

It is premature to discuss the relationships and successions of cenotes before the data collected have been worked up. The following remarks are therefore to be considered as tentative.

Davis¹ has pointed out that it is possible for caves to be formed (1) under the ocean by subterranean currents of water before land has been elevated, and (2) by the action of flowing or percolating water after land has been pushed up above sea-level. The appearance of caverns in Yucatan indicates that they fall largely or wholly in the first class. After observation in the field and discussion among members of the expedition, it was generally agreed that the history of a cenote was probably somewhat as follows: When Yucatan was elevated there were caverns in the limestone rock. These were large, irregular and often extended below the water table as established after elevation. The roof of such a cavern, if not already open, caved in piecemeal and thus a more or less open cenote was formed. The walls of the cenote continued to crumble away and add to the bottom sediments. The remains of animals and plants were added to such accumulations and formed bottom mud. After a time the bottom of the cenote was sealed over and communication with the ground-water was cut off. The cenote then gradually filled and became an aguada. The aguada became a swampy meadow and finally dry land.

The flow of underground water in Yucatan is apparently from the interior toward the ocean. All natives agree that the water-level in the cenotes rises a little after heavy rains, and during the dry season reaches a rather stable low level (which is probably about sea-level). All cenotes studied by Professor Hall had about the same salinity, whether they were in the interior or near the sea. The water in the caves was not essentially different in salinity from that in cenotes and aguadas, though certain of the aquatic cave animals may be looked upon as relics of an old marine fauna which existed when Yucatan was sea-bottom or an emerging shore. Springs and pozos of fresh water flow to the surface near and in the ocean. The level of ground-water in Yucatan is apparently raised temporarily by rains which percolate through the porous limestone above it. The water flows slowly toward the ocean until it stands at about sea-level. Then it remains more or less stable until rains raise it again.

A general report on the cenotes is now being prepared and various specialists are contributing. Papers on the following have been completed: Sponges, Marcus C. Old; Trematode Worms, H. W. Manter; Parasites, A. S. Pearse; Leeches, J. P. Moore; Mollusks, J. Bequaert and W. J. Clench; Cladocerans, A. S. Pearse; Decapod Crustaceans and Isopods, Edwin P. Creaser; Water Mites, Ruth Marshall; Odonata, E. B. Williamson; Bugs, H. B. Hungerford; Coleoptera, P. J. Darlington jr.; and Chemistry and Physics of Cenotes, F. G. Hall. Reports are in preparation by the persons indicated on the following: Introduction and Summary, A. S. Pearse; Copepod Crustaceans, C. B. Wilson; Ostracod Crustaceans, Norma C. Furtos; Spiders, A. M. Chickering; Fishes, Carl L. Hubbs; and Amphibians and Reptiles, Helen T. Gaige.

¹ Davis, W. M., *The origin of limestone caverns*, Science, vol. 73, 327-331, 1931.

SECTION OF UNITED STATES HISTORY

The work of the members of the staff of the Section of United States History on their respective projects is set forth below. This office has been largely engaged upon the usual correspondence and editorial processes connected with these projects. At the close of the last fiscal year three volumes were in process of publication and these have since been issued, namely, volume III of Mrs. Catterall's *Judicial Cases concerning American Slavery and the Negro*, published in December 1932; volume III of Miss Donnan's *Documents illustrative of the History of the Slave Trade to America*, published in December 1932; and Dr. Burnett's *Letters of Members of the Continental Congress*, volume VI, published in April 1933. In April of the present year the concluding volume of the text (volume VI) in the series of the *Correspondence of Andrew Jackson* was sent to the printer, and at the close of the year a considerable portion of it is in galley proof. Since the late Dr. Bassett completed the manuscript of the six volumes of this series, the Library of Congress has acquired a large number of papers of Jackson which he had placed in the hands of Amos Kendall for the purpose of preparing a biography, only a part of which was published. It had been understood that these papers, which were known to have passed into the hands of Francis P. Blair, were destroyed in a fire which burned a warehouse in Washington; but this acquisition of the Library of Congress represents that body of papers. While many of these papers parallel in content the materials already selected by Professor Bassett, it was deemed desirable that the concluding volume of text in our series should include an Appendix comprising such additional material from the collection as might be regarded as supplementary to that already published or of especial interest. The Section of United States History feels itself under great obligation to Dr. J. Franklin Jameson for having edited this additional material, as well as for having at all times, whenever called upon, given the various members of the Section his valuable advice and assistance. With the completion of the text of this series it only remains to bring out a general index, which will appear as volume VII, and upon which some work has already been done. Mr. David M. Matteson, who prepared the index to volume VI of the *Letters of Members of the Continental Congress*, has also made considerable progress on the index to the *Calendar of Manuscripts relating to the History of the Mississippi Valley*, although it should be said that we can hardly expect to have it ready for distribution before another year. As heretofore, the Section has been able to assist a number of scholars and students of history by placing at their disposal materials which have been collected in connection with its several projects under way and which await future publication. It is felt that this is a useful service and one which we are glad to extend to scholars and accredited students. The operations connected with putting the above-mentioned volumes through the press, as well as all correspondence of the Section, has been performed by Miss Cornelia M. Pierce, Secretary.

The Section is indebted, as it has always been, to the Librarian of Congress and to his official heads for many favors and privileges which have enabled the members of its staff to carry forward their work with much greater ease

and efficiency. To Dr. Waldo G. Leland, a member of this Section, although on leave of absence, and much occupied with other duties, the Section is indebted for valuable advice and suggestions.

Volume VI of *Letters of Members of the Continental Congress* was distributed during the early weeks of 1933. Volume VII, covering the period 1783-1784, has been completed and transmitted to the Division of Publications. One more volume will complete the series as planned, bringing the letters down to the inauguration of the government under the Constitution. While the greater part of the materials for this volume are in hand, considerable additions must be gathered from various archives, chiefly outside of Washington. These are mainly letters that have come to light or have become accessible since the materials were brought together some years ago. During the year the editor of this series has contributed to a coöperative *History of New York* a chapter on "New York in the Continental Congress."

One of the main enterprises of the Division for a long period was the *Atlas of the Historical Geography of the United States*. It was first planned in 1904, preliminaries were begun in 1912, and the work was placed in the care of Dr. Paullin in 1914, who, aided by many specialists, brought it to completion with its publication in October 1932. In April, Dr. Paullin, as author, jointly with Dr. John K. Wright, as editor, received the Loubat prize of \$1000 for the *Atlas*. This prize is presented every five years for the "best work in the English language on the history, geography, ethnology, philology, or numismatics of North America."

The preparation of the manuscript of the final volume of *European Treaties bearing on the History of the United States*, which covers the period 1715-1815, has been continued throughout the year. Miss Florence Spofford has completed the typing of photostats and Mr. C. K. Jones the translation of foreign texts.

In the investigation by Dr. Paullin of "Eminent Americans," which is based upon the sketches in the *Dictionary of American Biography*, progress has been made by abstracting information to the end of volume 5 and by a preliminary tabulation of much of this information to the end of volume 4. This initial labor has made it possible to reach precise conclusions respecting the varieties of usable materials, the methods of classification and the technique applicable to the investigation. In ascertaining the blood relationships of the characters, it was found desirable to supplement the information of the *Dictionary*, within the limits of the time available, with the materials found in the genealogies of the Library of Congress. Use is also being made of some of the materials collected by Dr. Charles B. Davenport, director of the Eugenic Record Office of the Carnegie Institution, Cold Spring Harbor, Long Island.

In December Dr. Paullin inspected the completed collection of Jackson papers recently acquired by the Library of Congress and selected the most important ones, which are to be included in the final volume of the *Correspondence of Andrew Jackson*, edited by Professor John Spencer Bassett. On December 30 he read a paper at the annual meeting of the Association for the Advancement of Science, held at Atlantic City, on "Biography from the Point of View of History." He has continued to act as treasurer and trustee of the Naval Historical Foundation.

Dr. Stock has continued his work of assembling and annotating the text for volume IV of his series, *Proceedings and Debates of the British Parliaments respecting North America*. In its present stage the text and notes of the record for Great Britain have been completed to 1740 and partially edited to 1746; for Ireland the work has been carried through 1736. During the year a considerable number of publications appearing in recent years have been examined for possible text and references that might be useful for purposes of annotation. Several of these sources were suggested by Dr. Jameson, whose interest in the project is constantly being shown.

Aside from his work on this volume, Dr. Stock has continued to serve as Chairman of the Committee on Publications of the American Historical Association and on that association's committee on Documentary Publications of the U. S. Government. He has continued as co-editor of the *Catholic Historical Review*, and his monthly List of Historical Articles to the *Historical Outlook*. He has also acted as American adviser in the selection of historical books for Rhodes House Library at Oxford. In the summer of 1932 he gave extension courses in history for the Catholic University of America at its session in San Rafael, California.

HISTORY OF YUCATAN PROJECT, BY FRANCE V. SCHOLES

The general program of research for the History of Yucatan Project was discussed in the Year Book for 1931. The first group of studies which has been started as part of that general program will deal with the Spanish Conquest and with the development of a Hispano-Indian society during the succeeding century and a half. The sources on which these studies will be based consist of printed chronicles and documents and of unpublished papers preserved in public and private archives and libraries in Europe and America. Most of the year 1931-32 was given over to a survey of the available printed materials in preparation for a comprehensive program of research in European archives and libraries. Archive work was started in April 1932, and the past fifteen months have been devoted to an intensive search for manuscript materials for the history of the general Yucatecan area in the major collections of Spain.

As the result of a cooperative arrangement by Harvard University and the Carnegie Institution, I have had the active assistance, since June 1932, of Mr. Robert Chamberlain, graduate student in Harvard, who is making a study of the career of Francisco de Montejo, Adelantado of Yucatan, for his doctoral dissertation. Mr. Lewis Hanke, also a graduate student in Harvard and Amherst Memorial Fellow for the year 1932-33, who is writing a dissertation on theoretical phases of Spanish Indian administration, rendered valuable assistance on numerous occasions. Acknowledgment should also be made of the courtesy of Professor C. U. Clark, formerly on the staff of the Smithsonian Institution, who gave me access to his notes on Central-Americana in European collections, accumulated during two years of research for the Smithsonian.

The most important Spanish depository of manuscripts relating to America is the Archivo General de Indias in Seville. For the history of Yucatan during the period of Spanish domination it is especially rich, and a conservative estimate of the total bulk of papers directly relating to Yucatan would

not be less than half a million pages. Besides searching the files of the strictly Yucatan papers, it has been necessary also to run through the vast series that pertains to general colonial policy and to the history of New Spain proper and of Guatemala. The sheer bulk of the materials made necessary the use of rapid methods of reproduction of the more important documents for future use and reference at home. Photostats were made of certain items, but the major portion of the reproductions were made with the Leica camera and 35-mm. moving-picture film. Enlarged prints have been made of a part of the films, but the amount of enlarging has been limited by budgetary considerations. Part of the unenlarged films can be read from projection, but this method has distinct limitations, of which not the least important is eye-strain. To the officials of the archive and especially to the director, Sr. D. Juan Tamayo, the Institution is deeply indebted for their kind consideration and sympathetic cooperation in making possible such rapid reproduction of materials essential to the success of the project.

The nature and contents of the materials which have been reproduced up to the present time are briefly indicated as follows: (1) Letters and reports of the provincial governors of Yucatan for the period to 1660; (2) letters of the treasury officers of the province to 1660; (3) correspondence of the cabildos of Merida, Valladolid, and Campeche to 1700; (4) letters and papers of the bishops of Yucatan and the cathedral chapter of Merida to 1700; (5) selected letters and petitions of private individuals, secular and ecclesiastical, taken from the general series of private correspondence for the viceroyalty of New Spain and the presidency of Guatemala; (6) selected correspondence of the Audiencia of Guatemala, the governors and bishops of Honduras, and the treasury officers of the Guatemala district for the period prior to 1550; (7) registers of royal orders for the province of Yucatan for the Sixteenth Century; (8) treasury accounts for the province of Yucatan for the Sixteenth Century and the first two decades of the Seventeenth; (9) a book of tribute assessments for Crown and encomienda towns in Guatemala, Honduras and Yucatan made at the end of the 1540's; (10) selected parts of a series of more than a hundred legajos of papers relating to confirmations of encomiendas in Yucatan, Sixteenth to Eighteenth Centuries; (11) the residencias of Montejo, Loaisa, Quijada and Céspedes, governors and alcaldes mayores of Yucatan in the Sixteenth Century; (12) linguistic materials from the residencias of Seventeenth Century governors; (13) trial records of private and state lawsuits illustrating phases of the career of Montejo and the practice of encomienda administration in Yucatan; (14) the file of papers relating to Landa's *auto de fe* against Indian idolatry in 1562 and Bishop Toral's investigation of the same; (15) a *matricula*, or village by village census, of encomienda Indians in Yucatan for the early 1680's; (16) four sets of documents on the theory of Indian administration, especially the problems of personal service, perpetuity of encomiendas, and levy of tithes, reproduced in cooperation with Mr. Hanke; (17) part of a long series of documents dealing with the Peten expeditions of the 1690's; (18) memorials, reports and lawsuits relating to a serious controversy between the Protector of the Indians and leaders of the Spanish ruling minority in the decade of the 1570's.

Work in the Archivo General de Indias has been carried forward without interruption during the past fifteen months. Meantime, investigations have been made in other Spanish collections. In the Archivo Histórico Nacional, Madrid, search was made in four sets of documents. In the papers proceeding from the Mexico tribunal of the Inquisition a few references to inquisitorial trials relating to Yucatan were found and will serve as a guide to future investigation in the papers of the Inquisition in the national archive of Mexico. A cursory examination was made of the residencias of late Eighteenth Century governors of Yucatan in the Council of Indies section. Groups of Franciscan papers were examined in the hope of finding information concerning Fray Diego de Landa during his residence in Spain in the 1560's, but the results were entirely negative. In the unpublished parts of the *Cartas de Indias* series several valuable items were found, of which the most interesting are a letter of Fray Luís de Villalpando denouncing the conduct of Yucatecan encomenderos and a brief survey of mission organization in Yucatan in the second half of the Sixteenth Century. Mr. Chamberlain also made a careful examination of the unpublished parts of Ayala's famous dictionary of government and legislation for the Indies and of parts of the *Cedulario Indico* of which it is the index.

The manuscript division of the National Library, Madrid, possesses a rich collection of Americana, but it contains little of special interest for Yucatan. In the library of the Academy of History, the most famous item for Yucatan is Landa's *Relacion de las Cosas de Yucatan*, many times published. Nothing more of vital importance for Yucatan was found. Mention should be made, however, of the copy, partly abridged, of Lic. Tomás López'¹ treatise on the climate, geography, flora and fauna, and aboriginal customs of the Indians of Middle America. This treatise has no great value as a whole, but the chapter on heathen gods and ceremonial practice, especially the short section on sacrifices at the cenote of Chichen Itzá, has some interest for the Americanist. The author of this report plans to publish this chapter. Due to the kind intervention of Professor Antonio Ballesteros and the Duke of Alba, Mr. Chamberlain was permitted to spend several days in the private archive of the Duke of Fernán Nuñez examining a series of papers relating to the Montejo family and later holders of the title of Adelantado of Yucatan. He found important materials concerning the ultimate disposition of the lawsuit between the Montejo family and the Crown resulting from the removal of Montejo as governor of Yucatan in 1549, and also detailed reports of the tributes of certain Indian villages in Yucatan later enjoyed by the Duke of Montallano, in whose family the title of Adelantado is still held. The Palace Library, formerly the private library of the kings of Spain, has been opened to students, and preliminary investigations have been made by Mr. Chamberlain and myself, but no report can be submitted at present concerning possible Yucatan manuscripts which it may contain. Finally, inquiry has also been made at the Convento Grande de San Francisco, the Naval Museum, the Ministry of Hacienda, and the Delegacion de Hacienda—in all cases with negative results.

¹ López was a judge of the Audiencia of Guatemala and special visitor of the province of Yucatan in the early 1550's. His labor in Yucatan had to do mostly with Indian affairs, and his name is always associated with a famous set of ordinances for the regulation of the same.

Brief visits have been made to a few collections outside Madrid: the Escorial; the provincial library, cathedral library, and Delegacion de Hacienda in Toledo; and the Archivo de Simancas. The provincial library in Toledo possesses an interesting original manuscript on Vera Paz and the Peten written in 1635 by the alcalde mayor of Vera Paz. Permission to reproduce this manuscript has been sought. In Simancas the Yucatan materials are few and scattered for the Sixteenth and Seventeenth Centuries. The most important are in the diplomatic series and relate to the intrusion of foreign corsairs and traders in Yucatecan waters.

The archive researcher is always inspired by something of the spirit of the professional prospector. He lives in the hope of finding some unexpectedly rich collection of letters, or of rediscovering some long lost chronicle. For the student of Yucatecan history there are many "finds" still to be made, for the list of missing manuscripts, linguistic and historical, is long. Realizing that the major Spanish collections had been combed many times for these lost manuscripts, I hoped that in ecclesiastical archives, especially the archive of the Franciscan Commissary General of the Indies, if still intact, some of them might be brought to light. To this end I sought the aid of my colleague, Dr. Stock, in order to obtain introductions to Spanish churchmen who might assist me in obtaining access to important collections. At his request His Excellency the Nuncio in Dublin sent me letters of introduction, one of them to the Nuncio in Madrid, who, in turn, put me in contact with several learned Spanish Franciscans. Unfortunately, the result of all this courteous cooperation has been only to indicate beyond any doubt that the once great Franciscan archives, especially the papers of the Commissary General formerly kept in the Convento Grande de San Francisco, Madrid, have been hopelessly dispersed, or in considerable part lost or destroyed. The same is true of the archives of those Franciscan houses which sent forth such men as Landa and Villalpando to labor in the missions of Yucatan. Fragments of these archives are now deposited in the Archivo Histórico Nacional, Madrid, but the legajos that were examined contain nothing of value for the Yucatan project. Thus was dashed to the ground my greatest hope of finding any of the important missing linguistic and historical writings of those Franciscan scholars who illumined the intellectual life of Yucatan in the colonial period.

In the Archivo General de Indias a few minor "finds" have been made. The most important is the *Relación* of the customs of the Indians of Yucatan written in 1582 by Gaspar Antonio Chi, often regarded as the chief authority on whom Landa relied when writing his *Relacion de las Cosas de Yucatan*. The nature of Gaspar Antonio's 1582 treatise has long been known through Cogolludo's use of it, but it was hoped that the original, if ever found, would contain much new information not used by that indefatigable ecclesiastical historian. The signed manuscript of Gaspar Antonio's treatise has been found in a series of miscellaneous papers in the Archivo General de Indias. Unfortunately it consists of only two folios, of which half of each has been torn away. Comparison with Cogolludo will make possible the reconstruction of almost every mutilated line in the original; in fact, Cogolludo used the original so well that its rediscovery will add little to our present stock of knowledge.

The general objective for which this archive program is merely the preparatory stage is a rounded study of Hispano-Indian society in Yucatan during the Sixteenth and Seventeenth Centuries. It was during that period that colonial society took form and the fundamental patterns of the culture of Hispanic America were permanently fixed. The Eighteenth and Nineteenth Centuries witnessed the culmination of certain trends and the reorientation of others, but the basic elements of society and culture were determined in that early period of readjustment during the first century and a half subsequent to the Conquest. Such a general view of Hispano-Indian society in Yucatan prior to 1700 must, however, presuppose the execution of certain preliminary and specialized studies in the form of articles or monographs in which the available materials can be dealt with in adequate detail.

(1) A thorough study of the career of Montejo is needed in order not only to do justice to one of the great figures in the conquest of Spanish North America, but also to set the Yucatan phases of it in proper relation to the whole. Mr. Chamberlain's work on Montejo will fill this need. It will be based on all the available manuscript and printed sources, and will deal with Montejo's labors as an associate of Cortés, the preliminary expeditions to Yucatan and Tabasco, his term as governor of Honduras and Chiapas, the final conquest of Yucatan, and the organization of provincial administration and society to 1549.

(2) Another figure in the early history of Yucatan whose career requires critical revaluation is Bishop Diego de Landa. Landa is known to us mostly for two things: his treatise on the Indians of Yucatan and the early history of the Spanish province and the famous *auto de fe* against Indian idolatry in 1562. The story of the Mani incident has never been properly presented, although J. T. Medina dealt with certain phases of it in his book on the beginnings of the Inquisition in America. Fortunately the Archivo General de Indias possesses the complete record of this affair, as well as numerous supplementary letters and reports, so that a critical study of this celebrated case is possible. Equally important is a survey of Landa's episcopate and of those conflicts of interest in which he took a leading part. A critical estimate of Landa's career may thus be made the basis of a detailed survey of the fluctuating conditions of provincial development during the first generation subsequent to the Conquest.

(3) A brief monograph on the population of Yucatan in the Sixteenth and Seventeenth Centuries will be valuable both for the historian and the ethnologist. An adequate estimate can be made by using the tribute payments as a basis, comparing the results thus gained with two or three special estimates that were made during the first century following the Conquest and with the *matricula* of encomienda Indians for the early 1680's.

(4) Adequate materials are now available for the investigation of numerous phases of Indian administration, of which the most important is the problem of the encomienda. The encomienda was introduced in Yucatan with the Conquest, and it lasted as a vital element of provincial life until the last quarter of the Eighteenth Century. Moreover, the proportion of encomienda villages to those administered by the Crown was approximately twelve to one, at least during the Sixteenth and Seventeenth Centuries, so

that it is difficult to overestimate the overshadowing importance of this institution in provincial society. In its ramifications, it was related to every other element of Yucatan life; in fact, analysis of this institution and its workings may be regarded as the warp on which the story of provincial society must be woven. The Archivo General de Indias contains more than a hundred legajos of documents relating to the encomienda in Yucatan, of which selected parts have been reproduced.

(5) Treatment of the subjugated Indians is but one phase of the general Indian problem. The unconquered and fugitive Indians of the interior of the peninsula of Yucatan were always a matter of serious concern to both State and Church. Series of manuscript materials now brought to light make necessary a reexamination of this entire question, not only in relation to some of its earlier phases, but also for the classic Peten expeditions of the late 1690's as related by Villagutierre. The original materials from which Villagutierre wrote his history of the conquest of the Itza are preserved in the Archivo de Indias, and reproduction of these papers for the use of the project has already been started.

(6) For ecclesiastical affairs, there are several topics which call for special treatment. I mention only three: (a) the beginnings of ecclesiastical organization and government; (b) statistical studies of missionary enterprise; (c) the role of the mission friar as defender and exploiter of the Indian.

(7) Although the materials which have been reproduced are essentially historical, they contain valuable information, direct and incidental, for the ethnology, ethnography and linguistics of Yucatan, Tabasco and the Peten. The survival of Indian ritual and ceremonial practice is discussed in several groups of papers. It is hoped that some contribution may be made to the knowledge of the shifting Indian groups in the interior of the peninsula, especially in the area between Campeche and Tabasco. Mr. Roys has found the cacique names that appear in numerous letters and legal documents valuable for his own studies. A document concerning the services of Gaspar Antonio Chi contains a few details concerning the Xiu family. Rather full information concerning Indian family names is found in the *matricula* of encomienda Indians noted above. Numerous incidental statements will help to illustrate the character of Indian village organization and the agricultural bases of Indian economy. But the most important materials are linguistic. Approximately three thousand pages of new Maya text, Spanish translation and accompanying explanatory documents will be available as soon as the program of reproduction is complete. A few of the new Maya texts date from the Sixteenth Century, but the major portion are found in the residencies of Seventeenth and Eighteenth Century governors, and consist of Maya translations of official decrees, depositions of Indian witnesses and related items. Much of this material is of a routine sort and there is considerable duplication of phraseology. On the other hand, a considerable number of the texts seem to have been written by native scribes, and Mr. Roys has informed me that some of the texts are unique in that they may serve as examples of the language for areas for which no known specimens have been available heretofore.

The archive program will be continued throughout the year 1933-34, with investigations in Spain, France, Italy and England.

SECTION OF THE HISTORY OF SCIENCE AND ALLIED INVESTIGATIONS

HISTORY OF SCIENCE—DR. GEORGE SARTON¹

Dr. Sarton returned to Cambridge on September 25, 1932, after an absence of almost fourteen months, the purpose of which was discussed in the last report. After his return he was obliged to spend considerable time in catching up with the work done by various scholars while he was away, and in studying a large number of publications which had accumulated in his office. He took pains to coordinate his observations and reminiscences, while these were still fresh, and to integrate them into the rest of his knowledge.

Having been honored by the University of California with the Hitchcock Professorship, he spent five weeks in Berkeley (Jan. 4 to Feb. 7) and delivered there eight lectures on Medieval science and culture (with special reference to the Mediterranean world and the Arabic writings). These lectures were his first attempt to coordinate the results of his studies and of his travels. He will prepare them for publication in a more elaborate form, for it is hoped that these lectures may reach a public for which the large and expensive volumes of the *Introduction to the History of Science* are rather forbidding.

There is good reason to believe that Dr. Sarton's California lectures will stimulate the "History of Science" movement in this country. The University of California is already doing more work in that direction than any other American university, or indeed than any European university, except those of London and Paris. That work is still in a preparatory stage, but we may expect it to develop strongly as soon as economic conditions are sufficiently improved.

Introduction to the History of Science—Dr. Welborn has continued her revision of the notes relative to Latin authors of the Fourteenth Century, chiefly physicians and mathematicians, and has amplified the bibliography considerably.

Dr. Pogo prepared elaborate notes on various authors of the first half of the Sixteenth Century, chiefly of mathematicians and cosmographers of Central and Western Europe.

Other investigations—Dr. Pogo has investigated the development of Egyptian water clocks from the time of Amenemhet (XVIIIth dynasty, c. 1550 B.C.) to the Greco-Roman period. He has prepared a critical edition to the *Libellus de locorum describendorum ratione* of Gemma Frisius (Antwerp 1533).

Dr. Welborn is undertaking a study of mediæval metrology, and has begun work on Dino di Garbo's table of weights and measures. She has begun a transcription of the *Canons of Johannes de Lineriis*.

Dr. Sarton has prepared an account of the life and work of the great Sixteenth Century mathematician, Simon Stevin of Bruges, and he has outlined the evolution of the decimal idea from the earliest times down to our own.

¹ Fifteenth annual report for the period extending from July 1, 1932, to June 30, 1933. (Previous reports appeared in Year Books Nos. 18 to 31; the 12th and following also appeared in *Isis*, the latest in vol. 19, 15-18.)

Miss Vera M. Gushee has been studying the development of scientific stellar astronomy before Hershel's time, with special reference to the works of Thomas Wright.

Publication of Isis—Dr. Sarton has edited, with Dr. Pogo's assistance, four numbers (52 to 55) forming the whole of volume 18, and a half of volume 19, a total of 934 pages with 10 plates. These four numbers contain 25 memoirs, 19 shorter papers, 31 reviews, 1721 bibliographical notes, and Mr. Guinet's index to volumes 16 to 18.

Lectures—In addition to the Hitchcock lectures already mentioned, Dr. Sarton delivered fourteen other lectures during his stay in California, most of them before various departments, seminars or groups of the University of California in Berkeley and in Los Angeles. He also spoke at Stanford University, and on January 27 lectured in Pasadena under the auspices of the Mount Wilson Observatory on the meaning of mediæval science.

After his return to Cambridge, he gave a course of about thirty-five lectures on the history of science in the Eighteenth and Nineteenth Centuries at Harvard University and a similar course at Radcliffe College.

RESEARCH IN PALÆOGRAPHY—E. A. LOWE¹

During the autumn and winter months field-work was carried on in Italy by two assistants, Dr. Lowe, for reasons of health, being unable to take part. In January, however, he paid a visit to the Bibliothèque Nationale, partly to examine certain manuscripts, partly to give the necessary instruction to two new collaborators who have since succeeded in completing the first survey of the entire Paris material.

Apart from brief visits to Paris, London and Winchester, the last six months were wholly spent in Oxford where, besides seeing the first fascicule of *Codices Latini Antiquiores* through the final stages of proof-reading, a certain amount of work was done on the *Codices Britannici* fascicule. Through the kind intercession of friends and the liberality and helpfulness of librarians, it was possible to have manuscripts sent to Oxford from the Cathedral Libraries of Hereford and Lincoln, from the University Libraries of Aberdeen and Glasgow, from the Fellows' Library of Winchester College, and from the Library of Lord Leicester at Holkham Hall. Sincere thanks are here expressed to the Venerable A. L. Lilley and Canon B. H. Streeter of Hereford Cathedral, Canon W. H. Kynaston of Lincoln Cathedral, Professor A. Souter and Dr. Douglas Simpson of the University of Aberdeen, Mr. W. R. Cunningham of the University of Glasgow, the Headmaster and Mr. Herbert Chitty of Winchester College, and Mr. C. W. James, Librarian to Lord Leicester; as well as to the officials of the Bodleian Library for acting as custodians of the borrowed treasures.

The new material which is being collected is growing daily in volume and scope. When digested and made available to scholars it is bound to render research in this field more fruitful and contribute sensibly to the widening of our knowledge concerning the oldest Latin manuscripts.

¹ For previous reports see Year Books Nos. 9-31.

HISTORY OF GREEK THOUGHT, BY W. A. HEIDEL¹

From July to October, I worked steadily in the British Museum on various phases of Greek scientific thought, particularly on the development of geography and the frame of history. One fruit of these studies has been published by the American Academy of Arts and Sciences as *A Suggestion Concerning Plato's Atlantis*, Plato's fiction being related to the geographical notions of the Ionians of the Sixth Century B.C. Two other studies are far advanced, one dealing with the frame, particularly with the parallels, of the Ionian maps and the confusion which resulted from the new conception of the earth as a spheroid and the consequent approximate location of the tropic; the other with the priest tales of Herodotus, Book II, which I expect to prove essentially taken from Hecataeus of Miletus, and to show how they furnished in part the scale for Greek chronology. Since my return to America in October, I have seen through the press my book, *The Heroic Age of Science*. I have also written an article, to be presently published, on the Agamemnon of Æschylus, in which the motive of the system of telegraphy by beacon-fires is related to the practice of kindling beacons at an ancient home-coming festival at Argos and at other points in Greece. Meanwhile my study of the early philosophers has gone on without interruption.

¹ For previous reports see Year Books Nos. 29-31.

DEPARTMENT OF MERIDIAN ASTROMETRY¹

BENJAMIN BOSS, DIRECTOR

The objective of the Department of Meridian Astrometry since its establishment in 1907 has been the production of a catalogue of definitive positions and motions of all the stars brighter than 7.0 visual magnitude, together with many fainter stars having motions larger than average. The program called for (1) modern determinations of the positions of the stars and (2) the comparison of all positions, old and modern, to determine their motions. The programs of observation were completed at San Luis, Argentina, in 1911, and at Albany, New York, in 1918 and the results were published in the San Luis Catalogue in 1928 and the Albany Catalogue in 1931. Along with the reductions of these observations the staff of the Department has carried the compilation of the observations made by others from 1755 to 1932. Since the publication of the Albany Catalogue, the entire efforts of the staff have been devoted to the compilation and comparison of all the observations and to the determination of the definitive positions and motions. It is gratifying to report that this program is rapidly nearing completion. The greater part of the more laborious and time-consuming operations have been finished and the card catalogue to contain all the information to be given in the General Catalogue is well under way. The two principal operations yet to be performed are the completion of the card catalogue of about 33,000 stars and the preparation from it of the manuscript of some 1800 quarto pages.

As evidence of the interest with which astronomers the world over are anticipating the publication of the General Catalogue, it may be noted that the Commission on Meridian Astronomy of the International Astronomical Union, meeting at Cambridge, Massachusetts, in September 1932, passed a resolution that this catalogue be adopted as a reference system for positions determined by photography and recommended that in the future meridian observers confine their observations to the stars contained in this catalogue plus a list to be compiled by a Committee of the Union of stars to be added in regions not well represented by the General Catalogue.

THE GENERAL CATALOGUE

REDUCTIONS

For explanation of the processes involved in the construction of the catalogue reference is made to the report of the Department for last year. The following details cover the progress made during the past year:

1. Star sheets and the application of systematic corrections for the southern circumpolar stars, noted as not completed last year, completed and checked.

2. Conditional equations for the last 500 P.G.C. stars and both northern and southern circumpolar stars formed and checked.

¹ Address: Dudley Observatory, Albany, New York.

3. Normal equations for the balance of the P.G.C. stars (3188) and northern miscellaneous stars (3513) and for all the southern miscellaneous stars (over 12,000) formed and 75 per cent of them checked.

4. Solutions of the normal equations giving the final positions and motions for the balance of the P.G.C. stars (4888) and the northern miscellaneous stars (7815) and for about 3000 of the southern miscellaneous stars were completed and checked.

5. Extension of the ephemerides to 1950 is completed and checked for all but the circumpolar stars.

6. Precessions and secular variations were computed for all the 14,515 northern miscellaneous stars and for about 2500 of the southern stars.

7. Third terms in the precessions were completed for the northern list.

8. Centennial variations in the proper motions were computed covering three-fourths of the northern stars.

9. The collation of the data in final form for publication has been carried beyond 10 hours of right ascension for the northern stars and is complete and partly checked beyond 6 hours.

10. A general search for unusual and gross errors has been started.

Items 1 to 3 indicate the completion of three major steps in the process of forming the catalogue. Items 4, 6, 7 and 8 show that considerable work remains to be done upon the southern stars. These steps, however, are not as time-consuming as those which have gone before and can be pushed through readily within the next year.

SYSTEMATIC CORRECTIONS

Raymond has completed an investigation of the systematic errors in right ascension depending upon stellar magnitude in the Preliminary General Catalogue. He finds that this error is very small and essentially linear, $\Delta\alpha_m = +0.0005$ (m—3.5), in the clock belt, and that it can have no sensible effect upon the proper motions. He does find small but apparently real errors outside the clock belt, as follows:

	$\Delta\alpha_m \cos \delta$
+90° to +70°	+0.0001
+70 " +30	+0.0008
—30 " —70	+0.0013
—70 " —90	+0.0027

These will not be corrections to the General Catalogue, however, as recent catalogues of high weight, observed so as to be free from $\Delta\alpha_m$ and showing a very small correction to the Preliminary General Catalogue, have been used in the reductions for the General Catalogue without the application of this form of correction. The result will be that the General Catalogue will differ less from the consensus of modern independent authorities than does the Preliminary Catalogue and we may reasonably hope that the final corrections required to make the General Catalogue free from magnitude error will be sensibly less than those given above.

DISTRIBUTION OF THE STARS IN THE CATALOGUE

As a matter of general interest and to facilitate the selection by the Committee of the International Astronomical Union of additional stars to approximate a uniform distribution over the sky, Wilson has constructed eight equal-area charts, six of them 16 by 24 inches, each covering four hours of right ascension from $+70^\circ$ to -70° in declination, and two of them covering the circumpolar areas, showing the distribution on the sky of the stars to be contained in the General Catalogue. These show clearly the well-known concentration of the stars toward the Milky Way, the larger open clusters, such as those in *Perseus*, *Taurus* and *Cancer*, and the effects of special lists of stars fainter than seventh magnitude which were added to the program after its inception.

MISCELLANEOUS

COOPERATION

The positions of 147 stars were furnished to Professor E. W. Brown of Yale University for use in the reductions of observations of occultations. Short lists of proper motions of stars of special interest were furnished to Professor S. A. Mitchell of the McCormick Observatory and to Dr. Keivin Burns of the Allegheny Observatory.

STAFF

The personnel of the regular staff has not changed during the year. Four part-time computers were employed to the end of the year 1932, at which time the part-time work was eliminated.

MOUNT WILSON OBSERVATORY¹

GEORGE E. HALE, HONORARY DIRECTOR
WALTER S. ADAMS, DIRECTOR
FREDERICK H. SEARES, ASSISTANT DIRECTOR

In a scientific organization such as the Observatory, the many investigations in progress may at first sight convey an impression of diversity and lack of relationship which on closer examination are not found to exist. The more general problems of astronomy may be defined as those which relate to the universe as a whole, including all the systems of stars, to the nature of our own stellar system, and to the properties of the stars of which it is constituted. Each of these problems is related to the others; for it is clear that no adequate knowledge of the outer systems of stars can be gained without an intimate comprehension of the one most accessible to observation; nor can we learn what we should of our own system without an understanding of the physical nature of the stars which compose it. Finally, the nearest of all stars and the one regarding which we can learn most is the sun.

Hence most of the researches at the Observatory form a consistent whole in which the parts are interrelated in a great variety of ways. The observer of the remote island universes calculates their distances by methods derived from stars within our own system, and the structure and even the continued life of each system are dependent upon the nature of the stars and the physical processes occurring within them. Essential to every research is the work of the physical laboratory, which aids in the interpretation of the observed phenomena and which through improved methods and improved instruments is constantly placing more powerful tools in the hands of the investigator.

An illustration of the bearing of a wide variety of observations upon an apparently unrelated problem is afforded by the distribution of the outer systems of stars, the extra-galactic nebulae, with reference to the Milky Way. These show a gradual falling off in numbers with approach to the plane of the Milky Way, until finally a zone of avoidance of irregular form is reached within which no nebulae are seen. The existence of clouds of cosmic dust within our system of stars is well known from direct photographic evidence, and, since the extra-galactic nebulae are observed through a portion of our system, the scattering and loss of light due to these clouds must affect the nebulae as well as the most distant stars of our galaxy. As a result, observations of color indices and spectra of faint stars, of open and globular clusters, of the interstellar calcium and sodium lines, and of the rotation of the galaxy from the distant Cepheid variables are all found to have a direct bearing upon the distribution of the nebulae.

Several important instrumental advances, in part facilitated through the cooperative plans for development of auxiliary apparatus for the 200-inch telescope, illustrate the value to the observer of close relationship to the physical laboratory. Among these may be mentioned the photoelectric amplifier of Dr. Stebbins and Dr. Whitford, which has made it possible to observe the radiation of fifteenth-magnitude stars with the 100-inch telescope. Another type of amplifier designed by Dr. Dunham enables the observer to measure directly the forms and intensities of solar-spectrum lines

¹ Address: Mount Wilson Observatory Office, Pasadena, California.

and thus eliminates the serious difficulties of photographic photometry. The correcting lenses calculated by Dr. Ross for the two large reflectors have greatly increased the available field and have multiplied several fold the value of these instruments for many kinds of photometric and astrographic work.

STAFF

Dr. George E. Hale, Honorary Director of the Observatory, has continued his investigation of the general magnetic field of the sun and has devoted much time to the plans for the 200-inch telescope. Dr. Walter S. Adams, Director, has carried on investigations in stellar spectroscopy. Dr. Frederick H. Seares, Assistant Director, has aided in the administrative work of the Observatory and has continued his photometric researches, in addition to serving as editor of the publications.

Dr. Arthur S. King, Superintendent of the Physical Laboratory, has been engaged in spectroscopic investigations, especially of the rare earths. Dr. John A. Anderson has continued as Executive Officer of the 200-inch telescope project and has undertaken a study of the spectra of several elements in the vacuum spark. Dr. Edwin P. Hubble has carried on investigations of the distribution, brightness and distance of extra-galactic nebulae. Mr. Harold D. Babcock has devoted much of his time to the ruling machines, but has also extended his work on the infra-red solar spectrum. Dr. Paul W. Merrill has been engaged in spectroscopic work on bright-line stars of various types. Professor Alfred H. Joy, Secretary of the Observatory, has completed an important investigation of the rotation of the galaxy based upon Cepheid variables. Dr. Seth B. Nicholson has continued his studies of solar activity and of stellar radiation. Dr. Francis G. Pease has divided his time between observations of the velocity of light and of stellar diameters with the 50-foot interferometer and the design of the 200-inch telescope. Dr. Adriaan van Maanen has directed the work on photographic measurements of stellar parallax and proper motion. Dr. Roscoe F. Sanford has been engaged in observations of the radial velocities of spectroscopic binaries and variable stars. Dr. Edison Pettit has carried on investigations of solar prominences and solar and stellar radiation. Dr. Walter Baade has continued photometric observations of nebulae and star clusters. Dr. Gustaf Strömberg has been engaged with problems in stellar statistics and stellar dynamics. Dr. Theodore Dunham jr. has made studies of high-dispersion stellar and planetary spectra and has given much time to the development of methods for measuring the absorption of spectral lines. Mr. Milton Humason has continued spectroscopic observations of extra-galactic nebulae and of faint stars. Dr. Sinclair Smith has used a photoelectric photometer for observations of faint stars and has been engaged in the design of such instruments for the 200-inch telescope. Mr. Ferdinand Ellerman has carried on solar observations and general photographic work. Dr. Robert S. Richardson has made photometric observations of sun-spots and studies of molecular spectra in the sun and stars. Mr. Joseph Hickox has been the regular solar observer on Mount Wilson and has had charge of the astronomical exhibits.

In the Computing Department Miss Louise Ware has used the large microphotometer in numerous photometric investigations of sun-spots, radiation across the sun's disk and the total absorption and contours of solar spectrum lines. Miss Elizabeth E. Sternberg has estimated solar and magnetic character-figures and has assisted Dr. Nicholson in the preparation of other data on solar activity. Mr. Edward F. Adams has measured spectrograms of sun-spots and of the limb of the sun and spectra for solar rotation. Miss Myrtle L. Richmond has measured and reduced all the records of ultra-violet solar radiation and has assisted in the reduction of measures of stellar radiation. Mr. Samuel L. Thorndike, who joined the staff on September 1, 1932, has shared in the observation and measurement of stellar parallaxes and proper motions. Miss Mary C. Joyner has taken part in the photometric investigations of Dr. Seares. Miss Cora G. Burwell has been engaged in studies of the spectra of stars showing bright lines and of stellar spectra in the infra-red. Miss Elizabeth MacCormack has carried on measurements of radial velocity on the Cassegrain and coudé spectrograms. Mr. Olin C. Wilson jr. has taken part in the radial-velocity work and in special studies of ultra-violet stellar spectra with the microphotometer. Mr. William H. Christie has used the moving-plate camera for photometric observations and has shared in the radial-velocity program. Miss Ada M. Brayton has given most of her time to computations relating to spectroscopic absolute magnitudes and parallaxes. Mr. Wendell P. Hoge has assisted in the study of infra-red solar spectra. Miss Elizabeth Connor has had charge of the library and has assisted in the editorial work.

Dr. Henry Norris Russell, Research Associate, Director of the University Observatory of Princeton University, has completed an important theoretical investigation on the physical conditions and constitution of stellar atmospheres. Dr. Joel Stebbins, Research Associate, Director of the Washburn Observatory of the University of Wisconsin, has applied a new photoelectric amplifier, constructed by Dr. Whitford, to observations of stars as faint as the fifteenth magnitude with the 100-inch reflector. Sir James Jeans and Dr. Charles E. St. John have continued as Research Associates of the Institution.

Abbé Le Maitre, Professor of Mathematics at the University of Louvain, visited the Observatory during February 1933 and on several occasions lectured on theories of the expanding universe before members of the staff. Professor Albert Einstein also visited the Observatory and took part in the staff meetings during his stay at the California Institute of Technology. During the summer of 1932 Dr. Frank E. Ross, of the Yerkes Observatory, made photographic observations of the Milky Way and tests of the correcting lens designed by him for the 60-inch reflector; he returned for further work in June 1933. Professor Frederick Slocum, Director of the Van Vleck Observatory, spent five months of the year in Pasadena and engaged in solar observations and tests of a Lyot coronagraph. Professor John C. Duncan, Director of the Whittin Observatory, made photographic observations with the two reflectors during his visit in the summer of 1932 and collaborated with Mr. Babcock in obtaining infra-red solar spectrograms. Dr. Knut Lundmark, Director of the Observatory of Lund, spent a few weeks of Janu-

ary in Pasadena examining the collection of nebular and stellar photographs. Dr. Alfred E. Whitford, of the University of Wisconsin, National Research Fellow in Physics, is assisting Dr. Stebbins in his observations of faint stars with the photoelectric amplifier. Mr. E. G. Williams, Commonwealth Research Fellow, has been engaged throughout the year in investigations of the ultra-violet spectra of stars with the microphotometer. Mr. L. E. Lefèvre, Commonwealth Research Fellow, has been measuring contours and the total absorption of lines on high-dispersion spectrograms of Cepheid variables. Dr. Serge A. Korff, National Research Fellow in Physics, has made an investigation of the spectrum of the corona and has developed apparatus for cosmic ray research. Dr. Robert B. King, National Research Fellow in Physics, came to Pasadena in June to continue his studies of the Zeeman effect in the sun-spot spectrum. Mr. Horace W. Babcock made observations of the infrared spectrum of the chromosphere on Mount Wilson during the summer of 1932.

Many astronomers and scientists in other fields have visited the Observatory for shorter periods of times. A noteworthy visit in August 1932 was that of a group of about twenty European astronomers and physicists who later observed the solar eclipse and attended the meeting of the International Astronomical Union at Cambridge.

Five members of the Observatory staff, Adams, Babcock, Dunham, Nicholson and Pettit, and three Research Associates, Russell, Stebbins and St. John, were present at the Cambridge meeting of the International Astronomical Union in September. Three members of the staff, Babcock, Dunham and Joy, attended the meeting of the Pacific Division of the American Association for the Advancement of Science at Salt Lake City in June 1933, and Adams and Dunham were at the general meeting of the Association in Chicago. Adams also attended the Atlantic City meeting of the Association and the Fifth Pacific Science Congress at Victoria and Vancouver.

SUMMARY OF THE YEAR'S WORK

Solar Research—Sun-spot activity is still decreasing and a fairly probable date for the minimum is October or November 1933. Average daily numbers decreased from 2.3 in 1931 to 1.2 in 1932. Polarities of 65 groups were observed in 1932, 62 of which had the regular sign; no spots of the new cycle have as yet appeared.

Direct photographs of the sun were made on 309 days between July 1, 1932, and June 30, 1933, and 1007 spectroheliograms were obtained in hydrogen and calcium light by Ellerman, Hickox, Nicholson and Richardson. Estimates of areas of hydrogen and calcium flocculi and of areas and positions of sun-spots have been continued regularly and sent to various cooperating organizations.

Measures by Richardson indicate that the ratio of intensity of both umbra and penumbra in sun-spots to that of the surrounding photosphere is nearly constant at different distances from the center of the disk. A fairly satisfactory agreement with observation can be obtained by assuming radiative equilibrium for umbra, penumbra and photosphere. Measures of faculae

show an increase of intensity relative to the photosphere as the limb is approached.

From studies of the Zeeman separations of lines on sun-spot spectrograms taken between 1915 and 1917, R. B. King finds a direct proportionality between separation and field-strength. Some evidence appears for decrease of field-strength with increasing level, but this relationship is still uncertain. The Zeeman patterns can not account for the abnormal strengthening in the spot spectrum of many faint satellite lines of multiplets.

A repetition by Pettit of thermocouple measurements of the energy of the photosphere along the sun's radius gives results in close agreement with those of 1921. The measures extend to within one per cent of the radius from the limb. The rate of radiation at the center of the sun is 1.17 times the mean value.

Visual observations by Pettit and Dr. Slocum on Mount Wilson early in June with a telescope of the Lyot type showed the solar prominences without difficulty, and photographs made with one-half second exposure were in good agreement with spectroheliograms of the same date. Pettit has made special studies of prominences present on the sun at solar eclipses and of small spiral prominences.

The ratio of the ultra-violet to the green radiation of the sun as measured by Pettit is now at its lowest value during the past nine years. The fall in the ratio from its maximum has followed in general the sun-spot curve.

Korff has concluded from several independent lines of evidence that the density of matter in the corona is insufficient, except in the lower levels, to produce resolvable spectrum lines. The mean level of the ionization is found to be 16.5 volts.

With the aid of standard lines of atmospheric oxygen, Babcock has established a reliable wave-length scale in the spectral region $\lambda 9000$ - $\lambda 10500$. He has also completed much of the work on the revision of the scale of intensities, the identification of water-vapor lines and the measurement of wave-lengths in the near infra-red.

Chromospheric spectra in the infra-red obtained by H. W. Babcock with the 75-foot spectrograph show numerous bright lines of astrophysical interest, including the strong triplet of ionized calcium, a line of neutral oxygen and nine members of the Paschen series of hydrogen.

In tests of a photoelectric cell and photron tube by Dunham, galvanometer deflections of 1000 mm. were obtained on the continuous spectrum of the sun in the second order of the 30-foot spectrograph. Deflections are very nearly proportional to light intensity, and single measures of the intensity of any point on the contour of a line are uncertain by less than one per cent.

Hale has applied photographic methods to the measurement of the sun's general magnetic field with the microphotometer and visual readings in observations with the photoelectric amplifiers of Dunham and of Stebbins and Whitford. About two-thirds of the results obtained with the last of these instruments are in harmony with previous determinations, but several discrepancies remain to be explained. Dr. Langer has measured with the parallel-plate micrometer many of the original spectrograms taken on Mount Wilson and confirms the results of the earlier measures.

Planetary Investigations—From a comparison with stars in Selected Area 51, Baade adopts a mean photographic magnitude for Pluto of 15.40. Results for different nights vary systematically between 15.2 and 15.4, but it is uncertain whether Pluto varies in light to this extent.

A study of spectrograms of Mercury in the region $\lambda 7500$ – $\lambda 8900$ by Adams and Dunham shows no evidence of differences from the solar spectrum.

High-dispersion spectrograms of the B-band in Mars, taken by Adams and Dunham over a period when the velocity of the planet with reference to the earth varied by 26 km./sec., show no evidence of the presence of a Martian component. The spectrograms have been measured directly and with the microphotometer. The accuracy attained justifies the conclusion that the quantity of free oxygen above unit area of the reflecting surface of Mars can not exceed one-tenth of one per cent of that above unit area at sea-level on the earth's surface.

Spectrographic observations by Dunham of individual lines in the bands of Jupiter and Saturn confirm Wildt's identification with the bands of ammonia and methane. Ammonia bands are relatively stronger in Jupiter and methane in Saturn. The intensities of the ammonia bands in Jupiter indicate the equivalent of a path 5 to 10 meters long at atmospheric pressure. A minimum temperature of 170° K is inferred.

Measures by Pettit and Nicholson of the radiation from Mars at every opposition from perihelion in 1924 to aphelion in 1933 establish a variation in the temperature of the sub-polar point from 27° C at perihelion to 0° at aphelion. Laboratory tests by Pettit indicate that variations in the quantity of atmospheric ozone can not materially affect measurements of planetary heat.

Researches on Nebulæ—From an investigation of 45,000 extra-galactic nebulae identified on 1300 plates, Hubble has outlined the zone of avoidance and concluded that within the errors of observation the distribution in the two galactic hemispheres is the same. There is no appreciable systematic variation in longitude, but the increase in numbers with latitude is well defined, following a cosecant law between 15° and 90° . The total obscuration at the pole is about 0.25 pgm. Except for occasional clusters, the distribution over the sky is random, and the increase in numbers with the exposure time of the plates is consistent with a uniform distribution in depth. The effect of red-shifts on apparent luminosities is under investigation.

A faint cluster in Corona Borealis, discovered by Hubble, shows about 600 nebulae, with a most frequent photographic magnitude of about 19.5, within a circle $30'$ in diameter. Its distance is of the order of 40 million parsecs. Baade has discovered a cluster in Cetus which includes 75 nebulae fainter than 18.3 within a circle $7'$ in diameter.

Thirty-one variable stars have been found by Baade in N.G.C.I 1613, a highly resolved extra-galactic nebula of irregular form. Its distance as derived from four of the brighter Cepheid variables seems to be much the same as that of N.G.C. 6822. Baade has also found variable stars in two other irregular nebulae.

A red-shift corresponding to a velocity of $+21,000$ km./sec., observed by Humason for one of the nebulae in the recently discovered cluster Corona Borealis I, is in excellent agreement with the value predicted by Hubble from its distance. A nebula in the very faint cluster Ursa Major II with a velocity of $+19,000$ km./sec. probably is a field nebula and not a true member of the cluster. Humason has also measured the velocities of four apparent members of the Virgo cluster and four objects identified provisionally as globular clusters and two novæ in the Andromeda nebula. The spectra and velocities of the novæ identify them as typical stars of this class belonging to the nebula.

Miscellaneous Stellar Investigations—Of great value to stellar research are the two correcting lenses designed by Dr. Ross for increasing the field of the large reflectors. Preliminary tests show excellent results. The five-inch camera lens giving a 20° field, also of his design, has been used by him for long-exposure photographs of regions in low galactic latitudes with the aim of extending his map of the Milky Way.

In addition to determinations of parallax and proper motion, van Maanen has derived new systematic corrections to ten of the modern series of trigonometric parallaxes which improve the agreement of the eight longest series very considerably. With the aid of these corrections, van Maanen has studied the distribution in absolute magnitude of all known stars within 20 parsecs and of 94 double-star systems with known orbits. The mean masses of the binaries agree closely with those derived from Eddington's mass-luminosity relation, but the masses of individual stars of the same luminosity show considerable dispersion.

From proper motions of the central stars of 21 planetary nebulae, van Maanen finds a mean photographic absolute magnitude of $+1.9$, a bolometric absolute magnitude of -0.8 and a probable density 100 or more times that of the sun.

Measures of stellar diameters by Pease with the 50-foot interferometer include $0''.0115$ for α Ceti, $0''.029$ for α Scorpii, and $0''.019$ for α Boötis. A diameter of $0''.040$ was found for α Scorpii in 1921, and the difference is believed to represent a real change. Strömberg has added to the double-star interferometer of his design a device for equalizing the effect of atmospheric disturbances on the images, as well as several other improvements.

In collaboration with Dr. Ross, who has furnished the observational material, Seares and Miss Joyner have determined the photovisual magnitudes of about 350 stars as supplementary standards in the Polar Sequence. The average deviation from the international system of a magnitude from one of the plates is about ± 0.05 mag., and for many of the stars the mean magnitudes are already comparable with the international magnitudes of the stars of the Polar Sequence. The systematic corrections necessary to reduce the existing catalogues of photographic and photovisual magnitudes of the polar region to the international system have been derived with most satisfactory results. The Greenwich effective wave-lengths have proved valuable in checking the relation of the photographic to the photovisual system.

Additional photometric investigations have included the determination of photographic standards for stars between magnitudes 18 and 20.5 by

Baade; observations of variable stars and of the integrated magnitudes of globular clusters by Christie; measures of the photographic magnitudes of about 20 faint stars of large proper motion by Thorndike; and observations by Smith with a photoelectric photometer of faint stars in the $+30^\circ$ zone of the Selected Areas.

Measures by Dr. Stebbins with the photoelectric cell show a reddening of practically every globular cluster of the sixty observed in the zone of avoidance of the extra-galactic nebulae. Colors of distant B-type stars in low galactic latitudes are similarly reddened. The accumulated effect of the cosmic dust clouds to which the reddening is due is to blot out all objects in the direction of the galactic center beyond a certain distance.

Baade is determining the distances of several faint globular clusters from cluster-type variables. In N.G.C. 6229 he has found 21 variable stars and is searching other clusters for adequate material.

On the assumption that our galaxy was formed by the encounter of two spherical systems of stars in each of which the physical characteristics of the stars permanently near the center differed somewhat from those of stars near the boundary, Strömberg has carried on a theoretical investigation of the dynamics of the galaxy which has led to a new formulation of the energy integral in the problem of three bodies.

The complete reduction by Pettit and Nicholson of their observations with the thermocouple shows that for six long-period variables of type Me the total energy reaches a maximum 50 days after maximum of light. The temperature, however, is a maximum at maximum light. The coolest star observed, χ Cygni, ranges from 2260° K to 1600° K. The mean amplitude of variation is: radiometric, 1.01 mag.; visual, 5.9 mag. The calculated average diameters range from 0'.033 to 0'.048. Four irregular M-type variables and five N-type stars also show a radiometric range about one-fifth the visual range. The radiometric magnitudes of the bright Cepheids η Aquilæ and δ Cephei are in phase with their light-curves. Temperature variations for the two stars are 670° and 800° , respectively, and the calculated diameters, 0'.0021 and 0'.0017, with ranges of about 15 per cent. Observations of Algol indicate that the temperature of the occulting star at principal minimum is probably lower than that of the primary star.

Stellar Spectroscopy—The stellar spectrograms obtained during the year, about 1650 in number, have been used for many special investigations. The radial velocities of about 100 stars with constant velocities have been measured. Orbits of spectroscopic binaries include determinations by Christie for Boss 9 and 283 and by Miss MacCormack for Boss 35 br. Sanford finds for α Orionis velocities which conform to the period of 5.781 years but with many short fluctuations. If the star pulsates, light-maximum occurs at minimum diameter and conversely. The velocity-curves of several Algol and Cepheid variables have been determined by Joy and Sanford.

A study of galactic rotation by Joy, based upon the radial velocities of 124 Cepheid variables, shows a well-marked rotational effect, conspicuous in the case of the more distant stars. The direction toward the center, in longitude 324° , is well determined. An absorption coefficient of 0.85 pg m. per 1000 parsecs of distance due to interstellar clouds brings the results into

harmony with theory and gives a linear increase in rotation amounting to 18.5 km./sec. for each 1000 parsecs of true distance. The center is 10,000 parsecs from the sun, and the solar velocity in a circular orbit about the center is 250 km./sec.

A catalogue now completed by Merrill and Miss Burwell lists 410 stars of types O, B and A showing bright hydrogen lines in their spectra, with notes, bibliographical material and statistical discussion. Bright lines occur most often in stars of type B2, and among early B stars probably one star in six shows bright lines. The divergence from the galactic plane characteristic of the local system is less marked for bright-line stars than for stars of the same apparent brightness with dark hydrogen lines; the absolute magnitudes of the emission stars are probably about one magnitude brighter.

In the near infra-red, Merrill has photographed many lines of astrophysical interest, including the Paschen series of hydrogen, the strong triplet of ionized calcium and lines of neutral oxygen, nitrogen, iron and titanium. Comparisons of infra-red spectra of N-type stars with electric furnace spectra of carbon show a remarkable correspondence extending over hundreds of angstroms.

Measures of the D lines of sodium on high-dispersion spectrograms of several giant M-type stars by Adams and Miss MacCormack give velocities which differ notably from those for the normal stellar lines. A lack of symmetry is shown by microphotometer tracings. The effect, which apparently is also exhibited by the H and K lines of calcium, can hardly be due to interstellar absorption but may be caused by an expanding stellar atmosphere.

Intensity measures by Sanford and Wilson of interstellar lines of sodium and calcium are in progress. From a study with the microphotometer of the Ca II lines in about 45 stars of types O and early B, Williams finds a correlation between intensity and color-excess as corrected for hydrogen line-absorption. There is, however, considerable scatter among individual stars not due to errors of observation. Bright-line B stars seem to be about 0.2 mag. redder than normal B stars.

The TiO bands in variables of type S often disappear at maximum, while the ZrO bands are but slightly weakened. Richardson has explained this effect by the higher heat of dissociation of ZrO, which he has calculated. A greater density for M-type as compared with S-type stars, and the greater abundance of TiO, would account for its prominence in M-type stars.

Several stars of remarkable spectra have been observed and studied by Merrill and Miss Burwell. Among these are three showing bright lines of ionized helium together with absorption bands of titanium oxide; H.D. 31293, in which the structure of the hydrogen lines varies greatly; and the unique star H.D. 190073, which shows bright D lines of sodium and complex H and K lines of calcium. Several variable stars observed by Joy have noteworthy spectra.

Measures of line-intensities used in determining absolute magnitudes have been nearly completed for about 4000 stars by Adams, Joy and Humason. Strömberg has computed the distribution of absolute magnitudes derived from trigonometric parallaxes for spectral types A, F, G and K with results which agree well with those based on proper motions and radial velocities.

Modern theory requires that for spectral lines of moderate intensity, the total intensity shall change slowly with increasing number of atoms. Dunham has confirmed this prediction observationally by measuring multiplets on high-dispersion stellar spectrograms with the microphotometer.

Russell has made a notable advance in spectroscopic theory by accounting for the variation in the intensity of spectral lines in a sequence of stars of different temperatures in which the opacity is due to the interaction of electrons and ions. Under these conditions, the lines of one element attain a maximum only if another element of easier ionization is present. The temperature at which the maximum occurs depends on the relative abundance of the two elements. The observed maxima indicate that a mixture of one atom of potassium to 3 of sodium, 12 of iron and 16,000 of hydrogen is a good approximation to a stellar atmosphere. Detailed calculations of the temperatures at which important lines are at a maximum in such a model atmosphere agree closely with observation.

Laboratory Investigations—In continuation of his studies of the spectra of rare earths, King has completed the temperature classification of 2863 neodymium lines and has measured new wave-lengths for 2026 lines. Lines of the neutral element seem in general to arise from two groups of closely associated energy levels. The study of the samarium spectrum has been extended to the infra-red. This element shows many unsymmetrical doublets from which a nuclear momentum of $0.5h/2\pi$ has been calculated.

King has also measured the Zeeman patterns of 280 cobalt lines and has made special spectroscopic investigations of calcium, barium, erbium, titanium and columbium. Strong bands of the CN molecule photographed in the infra-red spectrum of the furnace account for much of the structure of N-type stellar spectra.

Anderson is engaged in a study of the vacuum spark spectra of several elements with the large condenser. He has increased the frequency of oscillation for this instrument from 60,000 to 150,000 per second, thus multiplying the discharge current by a factor of 2.5.

Thermocouple measurements by Pettit and Miss Ware of the transmission of a water cell or microscope cover-glass show that the temperatures of a black body in the laboratory between 200° and $20,000^{\circ}$ K can be estimated without calibration against a standard of radiation. Tables have been constructed giving the temperature as a function of the transmissions.

An instrument for eliminating computation and converting microphotometer tracings of spectral lines directly into true intensities has been constructed by Dunham. Percentages of absorption at equally spaced intervals within the line are read directly from a logarithmic scale, the motion of the index being defined through a system of levers and rollers by the photometric reduction-curve.

A new galvanometer designed by Smith for use with the 60-inch telescope has a moving element so balanced that the instrument may be tilted as much as 45° from the vertical without serious effect upon the readings.

The new machine for ruling diffraction gratings has been completed and assembled, largely through the work of Prall of the instrument shop, and is

being given preliminary tests by Babcock. The diamond cutting machine has been rebuilt, and a few gratings have been ruled with the older ruling engine.

Pease is engaged in the reduction of the measurements of the velocity of light which were brought to a close by himself and Mr. Pearson on February 27, 1933. Fluctuations with an amplitude of about 20 km./sec. persisted throughout nearly the entire series of observations, beginning in 1931, which suggest a double variation with a short period of $14\frac{3}{4}$ days and a long period of one year. The irregularities are as yet unexplained. A third independent measurement of the base line in January and February 1933 showed no appreciable variation from earlier values.

OBSERVING CONDITIONS

During the year observing conditions were somewhat above the average for the past 21 years. Stellar observations were made on 299 nights and solar observations on 309 days. The observing record would have been even more favorable but for an extraordinarily heavy storm of snow and

Month	Observations			Month	Observations		
	All night	Part of night	None		All night	Part of night	None
1932:				1933:			
July.....	30	0	1	January.....	12	2	17
August.....	25	5	1	February.....	18	6	4
September....	25	3	2	March.....	18	9	4
October.....	17	8	6	April.....	15	8	7
November....	19	6	5	May.....	20	5	6
December.....	10	11	10	June.....	25	2	3
				Total.....	234	65	66
				Mean 21 years..	198	88	79

ice which began on January 15 and continued for two weeks. During this period, 82 inches of snow fell, and a break in the power transmission line and ice upon the buildings and domes interrupted observations for some time after the storm had passed. The total snowfall for the year amounted to 107 inches, but the precipitation, 24.28 inches, was 23 per cent lower than the 29-year average since the establishment of the Observatory. The extremes of temperature were 98° F on July 6 and 8, 1932, and 15° on February 25, 1933. The usual weather records have been maintained throughout the year.

The number of visitors using the 60-inch telescope for observations on Friday evenings was 6435, a somewhat smaller number than during the two previous years. Mr. Hickox has continued to give the regular lectures on these occasions and to supervise observations at the telescope.

The accompanying table shows the distribution of observing time with the 60-inch reflector throughout the year. The installation of roller bear-

ings in the wheeled trucks carrying the dome and the cleaning and repairing of the system of mercury flotation necessitated an interruption in the use of this instrument for 27 nights. Since this work was carried on during the winter, many of these nights were cloudy.

SOLAR RESEARCH

Minimum sun-spot activity for the present cycle has not yet been reached, nor have any spots of the new cycle as yet appeared. The generally accepted time of the last minimum was 1923.6, and phases of the present cycle have differed about ten and one quarter years from corresponding phases in the previous cycle. If this difference persists, the minimum of the present cycle should occur in October or November 1933.

The usual observations of the numbers, areas and polarities of sun-spots have been continued throughout the year, and daily records have been made with the spectroheliograph. Daily records of the horizontal intensity and direction of the earth's magnetic field have also been continued, and magnetic character-figures for each day have been published by the Department of Terrestrial Magnetism of the Institution. Special observations have included measurements of ultra-violet radiation, spectra and photometric studies of sun-spots, spectra of the chromosphere in the near infra-red, studies of prominences with a Lyot coronagraph and with the spectroheliograph, direct measurements of the contours and the total absorption of spectral lines with a photoelectric cell and amplifier, and an extensive series of photographs of solar spectra taken with a compound quarter-wave plate for the investigation of the sun's general magnetic field.

SOLAR PHOTOGRAPHY

Direct photographs of the sun were made with the 60-foot tower telescope on 309 days between July 1, 1932, and June 30, 1933, by Ellerman, Hickox, Nicholson and Richardson. The spectroheliograms include:

H α photographs of the disk.....	308
K ₂ photographs of the disk.....	294
K photographs of prominences.....	391
H α photographs of spot groups.....	14

Regular interchanges of spectroheliograms with the Kodaikanal and Paris Observatories have been continued throughout the year.

SUN-SPOT ACTIVITY

During the calendar year 1932 solar observations were made on 333 days. No spots were visible on 86 days, 20 of which were in September. Between July 1, 1932, and June 30, 1933, only eight groups large enough for photometric and spectroscopic study were observed. The two largest appeared in the winter, and one had the exceptional duration of at least 88 days, from November 16 to February 11. The monthly means of the numbers of groups observed daily during the past two and one-half years are given in the accompanying table.

The number of groups observed in the northern hemisphere of the sun decreased from 94 in 1931 to 43 in 1932; in the southern hemisphere, from 56 to 40. The mean latitude of the spot-zones decreased from $9^{\circ}2$ in 1931 to $8^{\circ}4$ in 1932.

Month	Daily number			Month	Daily number	
	1931	1932	1933		1931	1932
January.....	1.8	1.8	(1.4)	July.....	2.3	1.1
February.....	4.0	1.2	1.5	August.....	1.9	0.8
March.....	3.0	1.2	1.0	September.....	2.1	0.4
April.....	3.8	1.0	0.3	October.....	1.4	1.3
May.....	2.7	2.1	0.5	November.....	1.8	0.6
June.....	1.4	2.2	0.6	December.....	1.8	0.9
				Yearly average.....	2.3	1.2

Areas and positions of sun-spots on 46 days have been supplied to the Naval Observatory for publication in the Monthly Weather Review, and daily records have been communicated to Science Service at Washington. Estimates of character-figures of solar activity on 295 days in 1932 for calcium flocculi and on 301 days for hydrogen flocculi were forwarded to Professor Brunner of the Solar Physics Committee of the International Astronomical Union at Zürich. Values for the years 1916 to 1922 have also been sent recently and the series is now complete from 1916 to date. This work has been carried on by Nicholson and Miss Sternberg.

SUN-SPOT POLARITIES

The polarity and intensity of the magnetic field in sun-spots were observed on 203 days in 1932. The accompanying table shows the number of groups classified, "regular" groups in the northern hemisphere being such as show S (south-seeking), or negative, polarity for the preceding spot, and N polarity for the following spot, while the reverse is true in the southern hemisphere.

Hemisphere	Polarity		
	Regular	Irregular	Unclassified
North.....	32	3	8
South.....	30	0	10
Whole sun.....	62	3	18

PHOTOMETRIC STUDY OF SUN-SPOTS AND FACULÆ

Richardson finds that the ratio of intensity of a sun-spot to the surrounding photosphere at different distances from the center of the disk either is constant or else increases slightly toward the limb. The ratios for the center

of the umbra and for points half-way between the inner and outer edges of the penumbra are:

λ	Umbra	Penumbra
4330	0.10	0.70
5780	0.13	0.77
6450 (one point only)	0.24	0.89

The ratio of the intensity of the radiation from a sun-spot calculated on the assumption of adiabatic equilibrium to that from the photosphere based on radiative equilibrium decreases rapidly toward the limb, while the observed values are nearly constant. A satisfactory agreement with observation can be obtained, however, by assuming that the umbra, penumbra and photosphere are all in radiative equilibrium, at effective temperatures of 3900° , 5400° , and 5740° K, respectively.

Measured intensities of the faculæ relative to the surrounding photosphere for two wave-lengths are as follows:

Distance from center of disk	$\lambda 4330$	$\lambda 5780$
0.60	1.04	1.02
0.70	1.06	1.03
0.80	1.10	1.04
0.90	1.14	1.10
0.95	1.17	1.16

Minnaert and Wanders have based a theory of the faculæ on the fact that a rising column of gas expanding adiabatically will be brighter than its surroundings if the ratio of the specific heats is less than 1.33. A fair agreement with the above measures can be obtained by assuming a ratio of 1.14.

ZEEMAN EFFECT IN THE SUN-SPOT SPECTRUM

Photographs of sun-spot spectra taken on Mount Wilson between 1915 and 1917 with a Nicol prism and compound quarter-wave plate and the measured separations of the Zeeman components have been utilized by R. B. King in a study of the Zeeman effect in sun-spots. The separations when reduced and compared with theoretical and laboratory data appear to be definitely proportional to field-strength. Some evidence of decreasing field-strength with ascending level in spots has been found, but this result is much less certain because of many complicating factors. To the violet of $\lambda 6000$ the field-strength decreases with increasing intensity of the spot lines, but in the red this effect largely disappears. The abnormal strengthening in the spot spectrum of many faint satellite lines of multiplets apparently can not be accounted for by the character of their Zeeman patterns.

DISTRIBUTION OF ENERGY OVER THE PHOTOSPHERE

Improvements in galvanometers and thermocouples have made it advisable to repeat the measurements of the distribution of total energy along the sun's radius made in 1921. An air thermocouple having gold-leaf receivers

and a Moll one-fifth second galvanometer have been used, the galvanometer being provided with a timing device which registers one-second intervals from a chronometer. The arrangement permits measurements to within one per cent of the radius from the sun's limb. The accompanying values by Pettit were obtained in Pasadena.

r	0.0	0.2	0.4	0.6	0.8	0.85	0.9	0.95	0.96	0.97	0.98	0.99
1921	1.00	0.99	0.96	0.92	0.83	0.80	0.76	0.69				
1933	1.00	0.99	0.96	0.91	0.82	0.78	0.73	0.66	0.64	0.61	0.57	0.50

When weighted by areas of the contiguous zones and integrated for the whole disk, these values show that the rate of radiation at the center of the disk is 1.17 times the mean value, and that the temperature of the sun calculated from Stefan's law should be based on a solar constant of 2.28 calories $\text{cm}^{-2} \text{min}^{-1}$ instead of the customary 1.95. It is planned to transfer the apparatus to Mount Wilson for further measurements.

PROMINENCE OBSERVATIONS

Pettit has made a special study of all spots and prominences observed during eclipses since 1918. Five of the ten eclipses occurred when the sun had spots at the limb at eclipse time. Twenty-four photographs of the whole chromosphere made with the 13-foot spectroheliograph on August 31, 1932, show the development of several prominences before the eclipse of that date. A pair of prominences was noted in position angles 330° and 340° in which knots were moving from one prominence to the other with a velocity of 17 km./sec.

In order to obtain more material on the motions of prominences, the regular program with the 13-foot spectroheliograph has been increased to include six exposures on the whole chromosphere in calcium light. The larger prominences are also photographed in the $\text{H}\alpha$ line. During the summer of 1932 Pettit spent a month at the Yerkes Observatory, using the Rumford spectroheliograph in studies of the motions of small spiral prominences regarding the development of which little is known.

OBSERVATIONS OF PROMINENCES WITH A LYOT TELESCOPE

Following in general the plan developed by Lyot at Meudon, Pettit and Dr. Slocum have constructed an instrument for direct observation of prominences. An objective consisting of a simple crossed lens, 5 inches in diameter and 6 feet in focal length, is used with a combination of liquid and gelatine filters and special red-sensitive plates furnished by Dr. Mees of the Eastman Research Laboratories which limit the photographic sensitiveness to a narrow band extending from $\lambda 6400$ to $\lambda 6600$.

The instrument was attached to the side of the 60-inch telescope and first used on June 2, 1933. With a low-power eyepiece the whole circumference of the sun and the accompanying prominences could be seen without changing the position of the eye. The largest prominence was about one minute of arc in height and was estimated to be about twice as bright visually as

the sky background. Photographs with an exposure of one-half second record all the prominences seen and show a contrast with the sky background somewhat greater than that observed visually. The results agree with those from spectroheliograms in H α and K light and with visual observations made with the spectrohelioscope. Since success depends upon the elimination of scattered light, such an instrument must be pointed directly at the sun and can be used to advantage only when the atmosphere is very transparent.

ULTRA-VIOLET SOLAR RADIATION

Measurements of the ratio of the sun's energy at $\lambda 0.32\mu$ to that at $\lambda 0.5\mu$ have been made by Pettit over a period of nine years, on an average of 276 days a year, except during the first year when the apparatus was in the experimental stage. The average value for July 1932 to January 1933 was about 0.91; January to July 1933, 1.08. These are the lowest values since the beginning of the observations. The general fall in the ratio from its maximum of 1.5 has followed the general trend of the sun-spot curve.

PROPERTIES OF THE CORONA

The investigation of the width of spectral lines made by Dr. Korff last year has been applied by him to the lines in the spectrum of the corona. The density of matter in the corona as estimated from several independent lines of evidence corresponds to pressures of 10^{-9} atmosphere in the inner corona, and of from 10^{-11} to 10^{-14} atmosphere in the outer portions. At such pressures it would appear that there is not sufficient matter in the line of sight to produce resolvable spectral lines, except in the lower levels. Photographs of the corona through filters at the eclipse of August 31, 1932, showed no emission at heights greater than 150,000 km. above the limb.

At these pressures in the corona, there will be enough matter to emit by Rayleigh scattering the observed total light of the corona. The mean level of ionization as computed from the modified Pannekoek formula is 16.5 volts.

INFRA-RED SOLAR SPECTRUM

With the aid of the interferometer, Babcock has established a reliable wave-length scale in the spectral region $\lambda 9000$ – $\lambda 10500$, based on absorption lines of atmospheric oxygen present on the spectrograms as standards. The corrections to his earlier scale are small. The determination of relative wave-lengths with the 21-foot concave grating spectrograph has been continued, and the existing scale of intensities has been revised through visual comparison of standards of intensity, selected from the latter part of Rowland's Table, with lines on spectrograms taken under the same instrumental conditions. Comparisons of spectra from high and low sun have helped to identify water-vapor lines in the near infra-red. The use of a short air-path of 12 meters in the laboratory has made it possible to measure as fine sharp objects some of the water-vapor lines which appear in the solar spectrum as wide lines. Dr. Duncan has assisted in making the spectrograms both in Pasadena and on Mount Wilson.

INFRA-RED CHROMOSPHERIC SPECTRUM

During part of the summer of 1932, Horace W. Babcock observed the chromospheric spectrum in the near infra-red with the 75-foot spectrograph of the 150-foot tower telescope. Although the number of bright lines photographed is small, some of them are of great astrophysical interest. The most conspicuous objects are $\lambda\lambda 8498, 8542$ and 8662 of ionized calcium, which are widely reversed, $\lambda 8446$ of neutral oxygen, and nine members of the Paschen series extending from $\lambda 8503$ to $\lambda 9544$, all very diffuse.

PHOTOELECTRIC MEASUREMENT OF SOLAR ABSORPTION LINES

The use of photography as an intermediate step in the photometric measurement of the shapes of absorption lines introduces numerous complications and uncertainties. An experimental microphotometer operating directly in the solar spectrum has recently been tried by Dunham and found to give satisfactory results.

Light from the spectrum passes through a movable slit in the focal plane of the 30-foot or 75-foot Littrow spectrograph and into an evacuated cylinder containing a photoelectric cell connected with a photron amplifying tube. The lead from the cell runs directly to the grid without the use of insulators. Excellent stability has been obtained by the elimination of all commercial rheostats and potentiometers. The circuit is extremely simple and is operated from a storage battery of large capacity through a potential divider.

A 6-inch plane grating has been used in the second order. With the 30-foot spectrograph, the first and second slits are each 18 mm. long and 0.03 mm. wide (0.03 \AA). Under these conditions a potassium hydride cell produces 5×10^{-14} ampere in the continuous background of the spectrum at $\lambda 5000$, corresponding to a galvanometer deflection of 1000 mm. Since deflections are very nearly proportional to light intensity, the problem of calibration is practically eliminated. A single measurement of the intensity at any point on the contour of a line is uncertain by less than one per cent.

GENERAL MAGNETIC FIELD OF THE SUN

During the last two years Hale has devoted much time to the study of the general magnetic field of the sun. The special objects in view are a new determination of the strength of the field at different levels in the solar atmosphere and the explanation of some of the peculiar phenomena encountered in the earlier investigations, among them the apparently abnormal behavior of certain spectral lines and the effect of personal equation in the difficult task of measurement.

Several new methods of measurement have been submitted to comparative tests, including a careful series of trials of the Zeiss microphotometer, improved for this purpose by some new attachments, the use of the photoelectric amplifier in the form developed by Dunham for the direct measurement of the contours of solar lines and of the new photoelectric amplifier recently brought to Pasadena by Dr. Stebbins and Dr. Whitford. In the work with the microphotometer, new photographs taken with compound quarter-wave plates having mica strips wider than the 2 mm. used formerly have been found desirable to reduce the effect of grain and irregularities on the

tracings. Even with these plates, however, measurements made with the microphotometer on atmospheric lines do not show the desired high degree of uniformity. Studies have also been made of the slight film distortions detected and measured by Dr. Cooksey several years ago, and, through the kindness of Dr. Mees of the Eastman Laboratories, plates "normalized" by Cooksey's process have been prepared for this investigation.

A long series of measures on the line $\lambda 5247$ with Dunham's excellent amplifier and a circular quarter-wave plate above the Nicol prism in four position angles has failed to show displacements definitely attributable to the general magnetic field of the sun; but with certain improvements these minute displacements may yet prove to be measurable with this apparatus. More than two-thirds of the results obtained with the new amplifier of Stebbins and Whitford are in harmony with the previous determinations of the polarity and order of magnitude of the sun's general field, but several discrepancies remain to be explained. Much of this work has been carried on by Dr. Strong and Dr. Whitford.

Dr. Langer, of the California Institute of Technology, at Hale's request, has remeasured a number of the general magnetic field plates taken on Mount Wilson 20 years ago. His measures were made quite independently with the plane-parallel glass plate used previously and confirm the original conclusions regarding the existence, polarity and order of magnitude of the field.

The exacting requirements of this investigation have necessitated some important changes in the 75-foot spectrograph of the Solar Laboratory. Owing apparently to hysteresis, the tube showed for some hours after rotation in position angle motions which produced small but appreciable displacements of the spectral lines. A new rotating base has been made for the grating and collimating lens, which may be completely detached from the tube. With this arrangement the observed shifts have been eliminated.

COOPERATIVE OBSERVATIONS WITH THE SPECTROHELIOSCOPE

No great activity in work with the spectrohelioscope can be expected from newly enlisted observers during the present quiescent state of the sun when striking and important phenomena are rarely visible. Nevertheless, valuable systematic observations are in progress at several stations, especially Greenwich and Zürich. Other stations equipped with spectrohelioscopes are distributed around the world, and it is hoped that their cooperative work may ultimately lead to reliable conclusions regarding the relationship between certain solar and terrestrial phenomena.

THE SOLAR ECLIPSE OF AUGUST 31, 1932

Plans for the August eclipse involved the preparation of apparatus for direct photography, radiometric and photometric measurements of the corona and spectroscopic investigations of the corona and chromosphere extending into the near infra-red. The apparatus was constructed in the Observatory instrument shop and was designed in so compact a form that it was all transported in a single load on one of the Observatory motor trucks to Lancaster, New Hampshire, the site of the expedition.

The members of the staff forming the eclipse party were Adams, Babcock, Dunham, Ellerman, Nicholson and Pettit. The sky at Lancaster was completely cloudy at the time of the eclipse and no observations were attempted. Immediately following the eclipse the members of the expedition attended the meeting of the International Astronomical Union at Cambridge.

INVESTIGATIONS ON PLANETS

MAGNITUDE OF PLUTO

Comparisons of Pluto with stars in Selected Area 51 made by Baade on a number of nights during February and March gave a photographic magnitude of 15.40. The results for different nights were found to differ systematically over a range between 15.2 and 15.4, but it is still uncertain whether Pluto varies in light to this extent.

THE SPECTRUM OF MERCURY

Several spectrograms of Mercury were obtained by Adams and Dunham in July 1932, when the planet was near greatest eastern elongation. A 40-inch camera was used in the first order of the 9-foot plane-grating spectrograph at the coudé focus of the 100-inch telescope. The region covered by the photographs was from $\lambda 7500$ to $\lambda 8900$, where most of the strong bands in the spectra of the outer planets occur and where three bands due apparently to carbon dioxide were discovered in the spectrum of Venus. The linear scale of the spectrograms is 16.3 angstroms to the millimeter.

Comparisons with the spectrum of the sun and of Venus show no differences in the forms or intensities of the lines from the solar spectrum nor any evidence of the presence of bands. Terrestrial lines of oxygen and water-vapor are symmetrical.

OXYGEN IN THE ATMOSPHERE OF MARS

The B-band of oxygen with its strong widely spaced lines is particularly favorable for studies of the presence of oxygen in planetary atmospheres. During the past winter and spring, Adams and Dunham have used this band in an investigation of oxygen in Mars, the 9-foot plane-grating spectrograph at the coudé focus of the 100-inch reflector, which gives a linear scale of 5.6 Å per mm. in the first order, proving well adapted for the purpose. Special red-sensitive plates provided by the Eastman Research Laboratory, hypersensitized with ammonia, have been used for all the spectrograms.

During the interval covered by the observations, the radial velocity of the planet with respect to the earth varied from -13.8 km./sec. to $+12.6$ km./sec. These velocities would correspond to displacements of about 0.3 Å on the spectrograms, and oxygen lines of the planet, if present, should be fully resolved from the corresponding terrestrial lines. No evidence of such lines, however, can be detected visually or on tracings with the microphotometer. Measurements of 10 spectrograms show that the average position of 30 oxygen lines corresponds with the position of the terrestrial lines within nearly 0.001 Å. The conclusion seems to be justified that if the total absorption of a spectral line varies as the square root of the number of

absorbing atoms or molecules, the quantity of free oxygen above unit area of the surface of Mars can not exceed one-tenth of one per cent of that above unit area at sea-level on the earth's surface.

SPECTRA OF JUPITER AND SATURN

Dunham has photographed the spectra of Jupiter and Saturn with various cameras on the 9-foot plane-grating spectrograph from the visible red to beyond $\lambda 9000$. A number of the bands between $\lambda 6450$ and $\lambda 9100$ are clearly resolved, and Wildt's identification of some of the bands with those due to ammonia and methane is fully confirmed. More than 60 individual lines in the spectrum of ammonia photographed through a 40-meter pipe on Mount Wilson have been identified in the bands near $\lambda 6450$ and $\lambda 7920$ in the spectrum of Jupiter. Eighteen lines in the spectrum of methane agree in position with lines in the spectra of both Jupiter and Saturn in the adjacent unblended planetary band near $\lambda 8640$. The ammonia bands are much stronger in the spectrum of Jupiter than in that of Saturn, but the reverse is true for the bands of methane. A narrow band of intense absorption occurs in the spectrum of Jupiter near $\lambda 9750$, and four other less intense but wider bands appear between $\lambda 9750$ and $\lambda 10000$.

A rough comparison of the intensities of the band lines of ammonia in the spectrum of Jupiter with the laboratory results indicates that above the reflecting level in the atmosphere of Jupiter there is the equivalent of a path about 5 to 10 meters long through ammonia at atmospheric pressure. A minimum temperature of about 170° K for the reflecting level may be inferred, since at lower temperatures the vapor pressure of ammonia would be insufficient to support the observed amount of gas on a planet with the surface gravity of Jupiter.

RADIATION MEASUREMENTS ON MARS

The radiation from Mars was measured with the thermocouple by Pettit and Nicholson on March 1, 1933, when the planet was only 6° east of aphelion. Measures at every opposition from perihelion in 1924 to aphelion in 1933, although not yet completely reduced, establish the effect of orbital eccentricity on the climate of the planet. The temperature of the subsolar point varies from 27° C. at perihelion to 0° C. at aphelion.

The effect of ozone on measurements with the thermocouple in the region $\lambda 8\mu$ – 14μ has been tested by Pettit by placing an ozone tube with rock salt windows in the optical path of a small reflecting telescope. Measurements of the planetary heat from the moon show no sensible difference between results with no ozone in the tube and with three times the normal atmospheric content of ozone. It appears that variations of atmospheric ozone can not materially affect measurements of planetary heat.

RESEARCHES ON NEBULÆ

DISTRIBUTION OF NEBULÆ

An investigation of extra-galactic nebular distribution based upon some 45,000 nebulae identified on about 1300 plates with the large reflectors has been completed by Hubble. The results are as follows:

(a) The zone of avoidance along the Milky Way with its bordering partial obscuration has been outlined and its effects on apparent nebular distribution defined.

(b) Except for effects of this local obscuration, the distribution in the two galactic hemispheres is the same within the probable errors of the investigation (about one per cent).

(c) There is no appreciable systematic variation in longitude, but there is a well-defined increase in nebular density with latitude, following a cosecant law from about 15° to 90° , with a total obscuration at the poles of the order of 0.25 photographic magnitude.

(d) The frequency distribution of nebulae per plate indicates a random distribution over the sky, except for the presence of occasional clusters.

(e) Numbers of nebulae increase with exposure time according to a well-defined relation. The relation can not at present be interpreted without ambiguity, but is consistent with a uniform distribution in depth, subject to the influence of the red-shift on apparent luminosity.

(f) Extensive investigations of limiting photographic magnitudes of nebular images have led to a value 20.0 for an hour's exposure on Eastman 40 plates with the 100-inch telescope. The result permits the data on distribution to be expressed in terms of numbers per unit area to numerical limits and so leads to more reliable data on the distribution in space.

Investigations of the rate at which numbers of nebulae increase with exposure time have been pushed into regions where the effect of the red-shift on apparent luminosity should be, and apparently is, conspicuous. Further investigations of this subject, together with the necessary study of threshold photometry and the determination of diameter-luminosity relations in clusters at widely varying distances, form the major part of the current program. The general purpose is the investigation of the behavior of red-shifts beyond the limits of the spectrograph.

CLUSTERS OF NEBULÆ

A faint cluster of nebulae of exceptional interest because of its richness and compactness has been found by Hubble in Corona Borealis on one of the photographs taken for his survey of nebular distribution. Its position for 1933 is R.A. $15^h 19^m 7^s$, Dec. $27^\circ 56'$; galactic longitude 10° , latitude $+55^\circ$. Preliminary studies show about 600 nebulae within a circle $30'$ in diameter, the brightest having a photographic magnitude of about 17. The most frequent magnitude is about 19.5. These values, corrected for the effect of the red-shift, indicate a distance of the order of 40 million parsecs, in good agreement with that derived by the distance-velocity relation from the red-shift of $+21,000$ km./sec. measured by Humason on a spectrogram of one of the brightest members of the cluster.

Baade has discovered a cluster of faint nebulae on photographs of N.G.C. I 1613. The position for 1933 is R.A. $1^h 1^m 7^s$, Dec. $+1^\circ 40'$. Within a circle $7'$ in diameter are 75 nebulae with photographic magnitudes between 18.3 and the limit of the plates.

PHOTOMETRY OF NEBULÆ

In addition to the extensive photometric work involved in the study of the distribution of nebulae by Hubble, a detailed photometric investigation of the extra-galactic system N.G.C. I 1613 has been commenced by Baade. This is a highly resolved irregular nebula of the type of the Magellanic clouds. Thirty-one variable stars have thus far been found within it. Preliminary light-curves for four of the brighter Cepheids indicate that its distance is very nearly the same as that of N.G.C. 6822.

Variable stars have also been found by Baade in the Wolf-Lundmark-Melotte nebula, $23^{\text{h}} 58^{\text{m}}$, $-15^{\circ} 50'$, and in N.G.C. 4214. Both nebulae are of the irregular type.

NEBULAR SPECTROSCOPY

Several difficulties arise in attempting to photograph the spectra of individual objects in the faintest clusters of extra-galactic nebulae. On low-dispersion spectrograms the spectrum of the night sky begins to appear after an exposure of 20 hours or more; the spectra are exceedingly narrow, both on account of the short-focus camera lenses employed and the small diameter of these faint nebulae; and, finally, the probability of observing field nebulae not related to the cluster increases rapidly as the brightness of the objects decreases. An auxiliary window over the slit of the spectrograph outside the field of the nebula under observation is now in regular use to measure the effect of the spectrum of the night sky.

All these difficulties have been encountered by Humason in attempts to measure red-shifts in the two very faint clusters of nebulae, Coma Berenices II and Ursa Major II. A value of $+19,000$ km./sec. was observed in the case of what is apparently the brightest member of Ursa Major II, but since the red-shift in this cluster based upon the velocity-distance relation corresponds to about $+30,000$ km./sec., it seems highly probable that the object observed is a field nebula and not a member of the cluster. On the other hand, in the somewhat brighter cluster Corona Borealis I, discovered recently, the velocity of the one nebula observed is found to be $+21,000$ km./sec., in excellent agreement with the predicted value.

Humason has also measured the red-shifts of 23 brighter nebulae. Four of these, which appear to be members of the Virgo cluster, range from $+60$ to $+2850$ km./sec., a much larger range than might be expected from the previous observations of V. M. Slipher.

In the Andromeda nebula, M 31, observations have been made on four of the nebulous objects provisionally identified by Hubble as globular clusters. Their velocities range from $+80$ km./sec. to -540 km./sec., and their spectral types from F2 to F8. Two of the brightest novæ which have appeared in this spiral, numbers 106 and 107, when observed near maximum brightness, showed wide emission bands of hydrogen displaced toward the violet by amounts corresponding to velocities of -300 km./sec. The stars are thus identified as typical novæ belonging to this extra-galactic system.

Through the kindness of Lord Rayleigh the Zeiss lens used by him in observations of the spectrum of the night sky has been lent for use in the nebular spectrograph. It is a simple F 1.3 lens, corrected for infinity and

figured to an aspherical surface to reduce spherical aberration. Although the definition given by it is somewhat inferior to that of the Rayton lens, the gain in light due to less absorption and reflection is of great value, especially in the violet region where the H and K lines are of fundamental importance. A similar lens with an aperture of 45 mm. has been ordered and received from Carl Zeiss of Jena and is in regular use. The exposure times required for the Rayton lens when used with two prisms have been tested by means of 14 faint variable stars with well determined photographic magnitudes discovered by Baade in the Cygnus cloud. Under average conditions of seeing the exposure for a star of photographic magnitude 14.0 is about 60 minutes.

MISCELLANEOUS STELLAR INVESTIGATIONS

A 12-inch correcting lens designed by Ross for use at the primary focus of the 100-inch telescope to increase the field without appreciably changing the scale has recently been completed by Dalton in the optical shop. Tests by Pease and van Maanen show good images over a large field. The removal of a slight amount of spherical aberration by local figuring of the surfaces will be attempted later in the year.

Dr. Ross has continued his long-exposure photographs of regions in low galactic latitudes with the 5-inch lens of his own design with the object of extending the map of the Milky Way referred to in last year's Report. This type of lens is especially suited to the purpose because of its high photographic efficiency and large field of about 20° diameter.

TRIGONOMETRIC PARALLAXES AND PROPER MOTIONS

An increasing proportion of van Maanen's time during recent years has been devoted to observations of proper motion. The parallaxes of several stars, however, have been determined by him during the year, the most interesting of which is MW Cat. 27 in Selected Area 115. This is a star of photographic magnitude 16.5 with a considerable proper motion discovered by van Maanen and Willis. Its absolute parallax is $+0''.056$, and the corresponding absolute magnitude $+15.2$.

A new determination of the systematic errors in ten modern series of trigonometric parallaxes has been made by van Maanen with the aid of revised spectroscopic parallaxes derived by Adams. The eight longest series of parallaxes were found to show appreciable systematic errors depending on right ascension. The application of corrections derived independently for each series results in a considerable improvement in the agreement of the several series with each other.

A special study by van Maanen of the distribution of all known stars within a distance of 20 parsecs (65 light-years) shows 39 stars within a distance of 5 parsecs. The faintest of these stars, intrinsically, has a visual absolute magnitude of $+16.6$, and the great majority of all of them are of low luminosity. The three white dwarfs known at present all lie within the central region of 5 parsecs radius.

The parallaxes, corrected for systematic error, have also been used for a discussion of the masses of visual double stars for which orbits are known.

Ninety-four such systems are available. The mean masses for different absolute magnitudes agree closely with those derived from Eddington's mass-luminosity relation, but there appears to be a considerable dispersion among the masses of individual stars of the same luminosity represented by an uncertainty factor of 1.62 for cases in which both the parallaxes and the orbits are reliable.

Van Maanen has determined the proper motions of 15 planetary nebulae from measures of the central stars on several pairs of plates taken over a mean interval of about 12 years. The probable errors of the resulting motions are extremely small, about 0".001 in each coordinate. From the proper motions of a total of 21 planetaries van Maanen has derived a mean parallax of 0".00068. The corresponding mean photographic absolute magnitude of the central stars is +1.9 and the bolometric absolute magnitude -0.8. If the mass-luminosity relation indicates correctly the order of the masses of these stars, their densities must be high, perhaps a hundred or more times the density of the sun.

In a search for stars of large proper motion, Thorndike has made about 20 one-hour exposures on Selected Areas for comparison with plates of earlier date.

STELLAR INTERFEROMETERS

With the completion of his measurements of the velocity of light, Pease has been able to undertake further observations with the 50-foot interferometer. The rigidity of this instrument has been increased greatly by a few minor changes, and reliable observations can be made when the exacting requirements of stellar definition are satisfied.

Recent measurements of stellar diameters include:

	Mirror Separation	Diameter
α Ceti	40 to 42 feet	0".0115
α Scorpii	15 to 17	0.029
α Boötis	25	0.019

The result for α Ceti is new. The value for α Scorpii was obtained by extrapolation and indicates a smaller diameter for the star than in July 1921 when a value of 0".040 was found. The result for α Boötis confirms that obtained previously.

The double-star interferometer designed by Strömberg and described in the last Annual Report has been tested and improved in several respects. The most important modification is a device by which the full aperture of the telescope is utilized to produce two images of the same star, thus equalizing the effect of atmospheric disturbances on the diffraction images. Certain other improvements have not been completed and it is as yet impossible to judge of the performance of the instrument under actual observing conditions.

STELLAR PHOTOMETRY

Because of the urgent need of photometric standards fainter than the eighteenth magnitude for the study of variable stars in extra-galactic systems, Baade has spent considerable time in developing suitable methods of photometry with the 100-inch telescope. The diaphragm method used by

Seares with the 60-inch reflector was found to give consistent results; but a serious limitation of the method when applied to the 100-inch instrument lies in the fact that with so large an aperture, satisfactory results can be obtained only on nights when the figure of the mirror is undisturbed and the seeing steady. The extension of the photographic scale to magnitude 20.5 in four Selected Areas is well under way.

Christie has used the 10-inch Cooke refractor and moving-plate camera for the program of determining integrated magnitudes of the globular clusters within the reach of this instrument. He has also followed a number of variable stars systematically throughout the year. The photographic magnitudes of about 20 faint stars of large proper motion have been determined by Thorndike from photographs with the 60-inch telescope.

The attempt by Smith to determine the precise magnitudes and color indices of a number of faint stars in the $+30^\circ$ zone of the Selected Areas, with a photoelectric photometer at the coudé focus of the 60-inch telescope, has been continued with results which are not altogether satisfactory. The color indices agree well with those of Seares, but the magnitudes show considerable scatter. The source of the discrepancy is not known at present. A direct comparison of these stars with the Polar Sequence will be made with a new photometer at the primary focus.

EXTENSION OF THE POLAR SEQUENCE

With the assistance of Dr. Ross of the Yerkes Observatory, who has supplied extensive observational material, Seares and Miss Joyner have continued their investigation of the magnitudes of stars near the North Pole with the purpose of providing a large number of additional standards.

The gradually increasing application of large-field camera objectives to problems relating to the brighter stars has demonstrated the insufficiency of the existing polar standards for the rapid accumulation of photometric data. When only a dozen stars are available, the transfer of the scale to other regions of the sky becomes uncertain and the specification of the color system of the results highly ambiguous. In addition, there is the increased difficulty of determining the distance correction, which with these instruments is likely to be a function of magnitude and of direction from the optical axis, as well as of distance.

The investigation began with a study of the systematic corrections necessary to reduce the existing catalogues of photographic and visual or photovisual magnitudes of the polar region to the international system. Except for a slight shift in the color system, the photographic corrections presented at the Cambridge meeting of the International Astronomical Union in 1932 remain for the present substantially unchanged; the photovisual corrections, which have been slightly revised on the basis of supplementary observational data, should afford a reasonably accurate means of reducing the Yerkes photovisual and Potsdam visual measures to the international system. When thus corrected, the average deviation of a catalogue magnitude from this system for both the Yerkes Actinometry and the Potsdam Durchmusterung is ± 0.04 , and for the Potsdam Polar Catalogue, ± 0.065 mag. These deviations include all residual errors in scale, zero point and color equation.

The list of supplementary standards includes at present about 350 stars, consisting of all those brighter than about the eighth magnitude between 80° and 87° declination, and of all down to about the eleventh magnitude between 87° and the Pole. It is hoped later to widen the area for the fainter stars to a diameter of at least 10° and to extend the limiting magnitude for the immediate neighborhood of the Pole to 12.5 or 13.0.

The observational data already reduced include 24 photovisual plates taken with the 3- and 5-inch Ross lenses of the Yerkes and Mount Wilson Observatories and the 13-inch camera of the Flagstaff Observatory, all taken by Dr. Ross and measured by him with the thermoelectric photometer of the Yerkes Observatory. Under favorable conditions the average deviation from the international system of a magnitude from a plate taken with one of these instruments is about ± 0.05 mag. For many of the stars of the list, the precision of the mean magnitudes is already comparable with that of the international magnitudes of the Polar Sequence stars.

The provisional mean photographic magnitudes obtained by the reduction of existing catalogues to the international system are probably more accurate than the corresponding photovisual values because of the greater number of catalogues available (6 as against 3). Photographic magnitudes will, however, be independently determined to control the provisional results and to provide the precision desirable in supplementary standards. Sixteen plates taken by Christie with the 10-inch Cooke refractor and moving-plate camera have already been partially reduced and a number of others obtained by Dr. Ross with the 3- and 5-inch lenses are ready for measurement.

The Greenwich effective wave-lengths have proved especially useful in checking the relation of the photographic and photovisual systems to each other. The precision of these measures of color seems to be excellent. For 323 stars between magnitudes 4.5 and 10.0 the average difference in color index derived from magnitudes and from effective wave-lengths is ± 0.09 mag., inclusive of all errors in scales and color system and in the calibration-curve of the effective wave-lengths, which is used without systematic modification over the entire range in brightness.

GLOBAL CLUSTERS

Measures by Stebbins with the photoelectric cell of the colors of about 60 globular clusters have confirmed the existence of space reddening, especially in the direction of the center of the galaxy. Within Hubble's region of avoidance of the nebulae, practically every globular cluster is reddened, owing presumably to the scattering of light by dust in interstellar space. Similar measures of the colors of B stars with the large reflectors, which have extended to fainter objects the program of Stebbins and Huffer at Madison, also show that the region near the equatorial plane of the galaxy is filled with material the presence of which is revealed by the reddening of distant stars in low latitudes. Toward the galactic center, the accumulated effect of the dark material is to blot out all objects beyond a certain distance; but in the opposite direction, toward the anti-center, the absorption and reddening are less and we are able in spots to see out into the region of

the nebulae. This study is being continued by Stebbins and Whitford with the photoelectric amplifier on the 100-inch reflector.

Baade has made a study of a number of faint globular clusters outside the zone of obscuration for the purpose of replacing the relatively uncertain distances of these objects by values derived from cluster-type variables. The plates for N.G.C. 6229, in which 21 variable stars have been discovered, are complete. No variables were found in the new globular cluster N.G.C. 5694, discovered last year by Lampland and Tombaugh. The modulus (difference between apparent and absolute magnitudes) derived from the 25 brightest stars of this cluster is 17.94 magnitudes.

DYNAMICS OF THE GALAXY

Strömberg has been engaged in a theoretical study of the motions of stars in our galaxy on the assumption that it was formed by the encounter of two spherical systems of stars in each of which the stars permanently near the center had a somewhat different physical constitution from those near the boundary. Such an assumption would help to explain the observed dependence of motion upon the physical properties of the stars.

To solve the problem, it is necessary to know certain integrals relating to the problem of three bodies. A new formulation of the energy integral has been found which may prove of general value.

SPACE STRUCTURE AND MOTION

In an article entitled *Space Structure and Motion* (Science, vol. 76, 477, 504, 1932), Strömberg has considered the general problem of the nature of motion, analyzing the concepts of acceleration and rotation and discussing the observational criteria needed for distinguishing inertial reference frames from reference frames which are not inertial. The paper emphasizes the alternative ways of describing motion, one in terms of a constant Euclidean geometry and empirical physical laws, the other in terms of an empirical geometry and rational laws, and notes the possibility that a fine structure may be superimposed on the general structure of space in the neighborhood of the material singularities.

RADIATION FROM VARIABLE STARS

With the aid of the list of standard radiometric magnitudes, Pettit and Nicholson have reduced all their thermocouple measurements of the radiation from variable stars. Special attention has been given to long-period variables of type Me. Comparison of radiation- and light-curves for six of these stars shows that the maximum of light transmitted by the water cell follows that of visual light by 0.04 period, that of the radiometric magnitude by 0.1 period and that of the radiation eliminated by the water cell and of the bolometric magnitude by 0.14 period. Hence the total energy reaches a maximum about 50 days after maximum light, when the stars are visually 1.5 mag. fainter than at maximum. The temperatures, however, reach a maximum at maximum light, falling off faster than the light as the star approaches minimum. The average range is from 2350° to 1800° K. The coolest Me star observed is χ Cygni, which varies from 2260° to 1600° K. The

mean amplitudes for these variable stars are: radiometric, 1.01 mag.; visual, 5.9 mag.; bolometric, 0.89 mag.; water-cell absorption, 0.71 mag.

The average diameters computed from radiation data range from 0".033 to 0".048, the largest being 0".065 for R Hydrae. The velocity-curve of α Ceti deduced from computed diameters is in phase with that characteristic of Cepheids but opposite to that observed spectroscopically. If a constant diameter is assumed for Me stars, it is necessary to postulate a variable absorption to the violet of 1.4μ which is not in phase with the variations of total energy. Observations of 15 other Me stars confirm these results and reveal no abnormal temperatures of radiometric magnitudes.

For four irregular M-type variables and five of type N the range in radiometric magnitude is about one-fifth the visual range, a result similar to that for the Me stars. The lowest temperature found, for the N-type star V Cygni, seems to be less than 1500° K. R Cygni, type Se, resembles the Me stars in energy and temperature. Ten stars of exceptionally large color index, with magnitudes approximating those of the brighter Me stars at minimum, showed no sensible deflections when measured with the thermocouple.

Extensive observations of the bright Cepheids η Aquilæ and δ Cephei show that their radiometric and bolometric magnitudes and water-cell absorptions are in phase with their light-curves. Computed mean diameters are 0".0021 and 0".0017, respectively, with ranges of about 15 per cent. The ranges in brightness are: radiometric, 0.5 mag.; visual, 0.8 mag.; photoelectric, 1.1 mag. The progressive increase toward the violet indicates a variation of 1.5 mag. at $\lambda 0.32\mu$, an amount confirmed by the temperature variations of 670° and 800° for the two stars.

Observations of Algol during principal minimum give a radiometric range of 1.08 mag., while the photoelectric range is 1.20 mag. The difference probably indicates a lower temperature for the occulting star, although the temperatures of both stars are so high that they can not be differentiated with the water cell. Otherwise the radiometric and photoelectric curves have the same shape. The observed minimum, J.D. 2424110.7880, was 7 minutes later than that computed. This difference may be removed by using a mean period of 2.867310 days for the four-year interval separating the photoelectric and radiometric measures.

STELLAR SPECTROSCOPY

Few additions have been made to the stellar spectroscopic equipment during the year, but the existing instruments have been in very active use. The three-prism spectrograph with a 40-inch camera designed for observations of the spectra of relatively bright stars has been completed and tested. The ultra-violet spectrograph with its calibrating attachment has been used extensively in the study of B- and A-type stars and a few stars of later types. For work in the yellow, red and near infra-red, both the small plane-grating spectrograph at the Cassegrain focus of the 100-inch reflector and the 9-foot plane-grating spectrograph at the coudé focus have proved efficient, the larger instrument, which gives a linear scale of 5.6 Å per mm., being especially useful for the spectra of planets and bright stars. The high-dispersion spec-

trograms taken at the coudé focus have all been standardized with calibrating spectra photographed simultaneously with the stellar exposures by the method devised by Dunham.

Merrill has designed a type of slitless spectrograph for observing very faint stars in which a 13° prism is placed in the parallel beam of light between the two components of the Ross "zero-power" correcting lens at the Newtonian focus of the 60-inch reflector. The tests so far made indicate that this instrument should prove useful under good observing conditions.

The total number of spectrograms obtained during the year was 1605, of which 153 were with the coudé spectrographs, 243 with the plane-grating spectrograph and 192 with the ultra-violet spectrograph. In addition about 40 spectrograms of faint stars have been taken with the small nebular spectrograph. The observers have been Adams, Christie, Dunham, Humason, Joy, Merrill, Sanford, Strömberg, Williams and Wilson.

RADIAL VELOCITIES

In the course of the regular program, the radial velocities of slightly more than 100 stars have been determined from measurements of three or more spectrograms and several spectroscopic binaries have been discovered. Sanford has continued his observations of N-type stars and has now measured the velocities of about 120 stars of this class. The plane-grating spectrograph at the Cassegrain focus of the 100-inch telescope used with a 6-inch camera lens has proved efficient for these red stars.

The orbits of two spectroscopic binaries Boss 9 and Boss 283 have been computed and published by Christie, and the orbit of the F-type star Boss 35 br. has been nearly completed by Miss MacCormack. This star is the brighter component of a visual binary and its spectrum shows double lines with a period of variation of about 0.84 day. A spectroscopic binary of somewhat similar type, Boss 552, is under investigation by Wilson. Observations of the variations in radial velocity of H.D. 198287-8 and of several long-period spectroscopic binaries of late spectral type are being continued by Christie.

Sanford has completed and published studies of the radial velocities of two important variable stars, α Orionis and U Monocerotis. For α Orionis he finds velocities which conform to the period of 5.781 years derived by Jones but show many short fluctuations of considerable amplitude for which no definite period can as yet be found. The light- and velocity-curves are so related that if pulsation is involved light-maximum occurs at minimum diameter and conversely. The variation in diameter to be inferred from measures with the interferometer and from variations in radial velocity are in as good agreement as can be expected.

The star U Monocerotis belongs to the RV Tauri class of variables and appears to show a variation of 40 km./sec. in the velocity of its center of mass in a period of about 2300 days. The radial velocities when corrected for this effect give some evidence of a variation of double amplitude during the period of light variation. Between maximum and minimum of light the spectral type varies from F8 to G6, the hydrogen lines changing from emis-

sion to strong absorption lines and the G band increasing greatly in intensity. Titanium oxide bands appear at minimum.

The radial velocities of a number of short-period Algol variables are under investigation by Sanford and Joy, and velocity-curves have been derived by Sanford for the five stars UU Cassiopeiae, RW Coronae Borealis, AK Herculis, CM Lacertae and AG Virginis. Sanford has also been observing the velocity-curves of the Cepheid variables Y Ophiuchi and FF Aquilae to confirm changes in form suggested by earlier observations. Several large radial velocities have been found by Joy in the course of observations of short-period variables of the RR Lyræ class.

GALACTIC ROTATION AND SPACE ABSORPTION FROM CEPHEID VARIABLES

Joy has utilized his determinations of the radial velocities of 134 Cepheid variables, for 96 of which no previous velocities were known, in a study of the galactic rotation and space absorption. These stars are especially well adapted to this purpose on account of their small peculiar motions, high galactic concentration, great distances and the quality of their spectra. The material includes nearly all Cepheids north of declination -35° and brighter than the fourteenth photographic magnitude at maximum.

The stars were divided into four nearly equal groups according to their distances, which were determined from a period-luminosity correlation based on photographic median magnitudes. The rotation was determined by Oort's method, the K term, which is less than 2 km./sec., and the terms of the second order being omitted. The rotational effect is well marked and conspicuous in the case of the more distant stars. The direction toward the center, in longitude 324° , is well determined.

The rotational effect does not, however, increase linearly with distance as predicted from theory. This discrepancy may be avoided by correcting the distances for the effect of an absorbing medium, the existence of which is now well established by many independent lines of evidence. An absorption factor of 0.85 photographic magnitude per 1000 parsecs gives a linear increase in rotation amounting to 18.5 km./sec. for each 1000 parsecs of true distance. The estimated distance of the center is 10,000 parsecs from the sun; the solar velocity in a circular orbit about the center is 250 km./sec.; the corresponding rotation period, 240,000,000 years.

B-TYPE STARS WITH EMISSION LINES

The catalogue and bibliography of stars showing emission lines, by Merrill and Miss Burwell, which is now in press, lists 410 stars of types O, B and A whose spectra have bright hydrogen lines. Many unpublished data and the chief features of certain of the more interesting peculiar spectra are collected in the notes to the catalogue. The bibliography includes 365 references to observational material concerning the objects catalogued.

A brief statistical discussion lists the numbers of stars discovered at various observatories, shows the distribution of the Be stars according to type and magnitude, and compares the numbers of these stars with the total numbers of stars in the Henry Draper Catalogue. The largest numbers occur in spectral subdivision B3 and magnitude 8. The proportion of bright-

line stars is greatest in class B2 and decreases very rapidly from B3 to A0. The data are incomplete, but it seems probable that one star in every five or six of the early B stars, at least those of class B2, has bright lines. Comparison of average galactic latitudes at various points along the galaxy indicates that the divergence from the galactic plane characteristic of the local system is less strongly marked for emission than for non-emission B stars of the same apparent magnitude and disappears at a brighter limiting value. The emission stars are probably about one magnitude brighter intrinsically than the others; consequently the boundary of the local system is reached at a somewhat brighter apparent magnitude. The Be stars are especially numerous in ten or twelve areas, which are listed. Some of these areas probably represent groups of stars relatively near us, while others are portions of Milky Way star clouds seen between clouds of absorbing material. The distribution of faint Be stars closely resembles that of faint Cepheid variables, probably because these intrinsically bright objects are so distant that their apparent distribution is largely determined by the location of dark absorbing clouds.

SPECTRA IN THE NEAR INFRA-RED

Merrill has used the Cassegrain grating spectrograph in a study of various types of stellar spectra between $\lambda 7000$ and $\lambda 9000$, a region open to easy investigation by some of the sensitizing dyes recently discovered by the Research Laboratory of the Eastman Kodak Company. Numerous lines of astrophysical interest are being examined in the region $\lambda 8320$ to $\lambda 8900$, where terrestrial lines do not interfere seriously with the observations. Among these lines are several members of the Paschen series of hydrogen not previously observed in any source; the strong triplet of ionized calcium; a line of neutral oxygen at $\lambda 8446$; and numerous lines of neutral nitrogen, iron and titanium. The Balmer and Paschen series of hydrogen lines in stellar spectra are being compared photometrically by Merrill and Wilson.

A comparison of the infra-red spectra of N-type stars with the spectrum of carbon obtained by King with the electric furnace shows a remarkable correspondence extending over hundreds of angstroms and indicates that a large proportion of the complicated spectral detail is due to a carbon compound, probably cyanogen.

A few spectrograms of bright stars extending to $\lambda 9000$ have been obtained with the coudé grating spectrograph. The high dispersion of these spectra is most useful in the separation of stellar from atmospheric lines.

SODIUM LINES IN STELLAR SPECTRA

Measurements by Adams and Miss MacCormack on high-dispersion (5.6 Å per mm.) coudé spectrograms of certain bright stars show marked differences in the displacements of the D lines of sodium from those of normal stellar lines and a notable lack of symmetry in the contours of the D lines. For the M-type stars α Orionis, α Scorpii, α Herculis and β Pegasi, the sodium lines give in all cases larger negative velocities than the other stellar lines, the differences occasionally amounting to as much as 7 or 8 km./sec. The K-type star α Boötis and the M-type star δ Ophiuchi show no such effect,

nor do γ Cygni and α Persei, stars of a Cepheid-type spectrum. The abnormal displacement can not be due to interstellar sodium, since the radial velocity given by the sodium lines in some cases exceeds both the velocity of the star and the component of the solar motion in the direction of the star. The stars in which this effect has been found are all supergiants of type M, and provisionally it may be ascribed to an expanding atmosphere or to clouds of sodium gas associated with the stars. The character of the H and K lines of calcium in the spectra of these stars points to similar behavior on the part of these lines. It will be of interest to correlate the velocities given by the sodium lines with variations of light and interferometer measures of diameter.

Differences between the values given by the sodium and the other stellar lines have also been found in the spectra of α Cygni and β Orionis, but in these cases the effect is probably due to interstellar sodium. Microphotometer tracings by Wilson show a lack of symmetry in the sodium lines of α Cygni which may be ascribed to the combination of a faint stellar line with a stronger interstellar line, the difference in radial velocity being insufficient for resolution of the lines even under high dispersion.

The yellow portion of the spectra of numerous B-type stars is being investigated by Wilson and Williams with especial reference to measurements with the microphotometer of the intensities of interstellar sodium lines.

CALCIUM LINES IN STELLAR SPECTRA

Systematic observations with the three-prism ultra-violet spectrograph of stars of early-type spectrum and a large range in apparent magnitude, but within narrow limits of position, are being undertaken by Sanford for a quantitative study of the interstellar lines of calcium.

With the same instrument Williams has studied the correlation between color excess and the intensity of the interstellar calcium lines in a number of O- and early B-type stars. The spectrograms were standardized and reduced with the aid of the photoelectric microphotometer. In so far as color excess is produced by space absorption, such a correlation would be expected, since both parameters depend statistically on distance. The color excesses used have been those determined elsewhere photoelectrically, and when based on ultra-violet color indices they require a correction for hydrogen line-absorption. This correction, which for some early B-type stars is as large as 0.2 mag., was found by a spectrophotometric comparison of the energy distribution in typical B stars with that in stars showing a nearly continuous spectrum in the ultra-violet.

The Ca II line-intensities for some 45 stars show a statistical correlation with the corrected color excesses. There is considerable scatter which is not due to errors of observation. All the bright-line stars observed are too red for their interstellar calcium intensity, and, since this intensity is probably a reasonably good criterion of distance, it appears that the bright-line B stars are some 0.2 mag. redder, on the usual color-index scale, than normal B stars. This difference corresponds to effective temperatures some eight or nine thousand degrees lower.

TITANIUM AND ZIRCONIUM OXIDE BANDS IN STELLAR SPECTRA

Richardson has calculated the constants in the equation of dissociation equilibrium for ZrO and used the equation to find the percentage of ZrO dissociated at various temperatures and pressures. Similar computations have already been made by others for TiO. These results have been used to account for the general nature of the spectral changes in S- and M-type stars.

In variables of type S at maximum the TiO bands often disappear, and the ZrO bands are slightly weakened. This is due to the higher heat of dissociation of ZrO. At 3000° K and a pressure of 10^{-6} atmosphere, TiO is wholly dissociated, while ZrO is only 60 per cent dissociated. The fact that TiO alone is seen in type M stars can be explained if their density is greater than stars of type S. If the pressure is so high that neither TiO nor ZrO is appreciably dissociated, then the TiO bands will be by far the more conspicuous owing to the greater abundance of Ti.

PECULIAR SPECTRA AND SPECTRA OF IRREGULAR VARIABLES

Four stars showing bright helium lines in their spectra have been observed by Merrill, in three of which bright lines of ionized helium are accompanied by absorption bands of titanium oxide. This anomalous combination, now known in six objects, seems to result from a definite set of physical conditions, among which low pressure is probably essential.

The remarkable spectra of H.D. 31293 (AB Aurigæ) and H.D. 190073, type A0ep, have been studied by Merrill and Miss Burwell. The structure of the hydrogen lines in H.D. 31293 varies greatly, the positions of the cores of the lines moving through a range corresponding to 115 km./sec., while the wings remain nearly fixed. The spectrum of H.D. 190073 is unique among known stellar spectra. The sodium lines D_1 and D_2 are bright, while H and K of calcium show a remarkable structure consisting of a narrow dark line fringed with weak emission and an intense absorption band or space 3 Å wide, displaced 3.2 Å toward shorter wave-lengths.

Among variables of irregular or unknown period, Joy finds for UY Aurigæ a spectrum similar to that of T Tauri with strong bright hydrogen and H and K lines. V Sagittæ shows a Wolf-Rayet spectrum with strong continuous background and a prominent ionized helium line at $\lambda 4686$ about 20 Å in width. The spectrum of RU Coronæ Borealis is of type M7 with no emission lines, and that of AX Sagittarii resembles that of R Scuti with strong enhanced lines.

SPECTROSCOPIC DETERMINATIONS OF LUMINOSITY AND PARALLAX

Independent measures of the intensities of the lines used in deriving the absolute magnitudes of stars have been continued throughout the year by Adams, Joy and Humason in preparation for the publication of a catalogue containing about 4000 stars. The measures by Adams and Humason have been completed and those by Joy are well advanced. The material includes nearly all the stars in the *Preliminary General Catalogue* of Boss of types A5 or later which can be observed at Mount Wilson, as well as many

fainter stars of large proper motion, visual binaries and other stars selected from special observing lists.

For purposes of comparison with values derived by other methods, Strömberg has computed the distribution of absolute magnitudes for stars of spectral types A, F, G and K from the distribution of trigonometric parallaxes by a process similar to that employed in the case of proper motions and radial velocities. The method involves the numerical solution of certain integral equations of complicated form. It is somewhat more laborious than that used for proper motions and can not give quite such high accuracy for the most luminous stars; nevertheless the results agree well with those obtained previously.

STELLAR SPECTROPHOTOMETRY

The coudé spectrographs, which may be adapted to many different forms according to the brightness of the stars and the spectral region observed, are proving most efficient in studies of line-contours and total absorption. A linear scale as great as 2.7 Å per millimeter may be attained in the yellow and red portions of the spectra of late-type stars, a dispersion adequate to resolve fully most of the important lines and to reveal with considerable accuracy the contours of absorption lines with intensities as great as 6 on Rowland's scale. Calibrating spectra are obtained by means of the auxiliary step-slit attached to one side of the stellar slit.

Dunham is undertaking the measurement of a large number of unblended lines in the spectra of several of the brighter stars for the purpose of determining the temperatures and pressures in their atmospheres from the degree of ionization exhibited by different elements. The ionization depends on the relative numbers of neutral and ionized atoms, which must be inferred from the integrated absorptions of the lines. The curve relating these two quantities may be computed theoretically for an assumed stellar temperature. When the number of active atoms is small the contour of the line is determined by thermal Doppler effect, and the integrated absorption varies directly as the number of atoms concerned; but when the number of active atoms is large the contour of the line is controlled by radiation damping, and the total absorption is proportional to the square root of the number of atoms. In the region of transition between these extremes, the total line intensity changes very slowly as the number of atoms increases. The curve relating the numbers of atoms and the total absorption of the lines may also be determined empirically from measurements of lines in multiplets, for which the relative intensities of the component lines are known from theory when interlocking is unimportant. The results of both methods of calibration are being compared. Preliminary measures of lines of moderate intensity in a number of multiplets show the slow change in total intensity with increasing number of atoms which is to be anticipated theoretically.

Lefèvre has been engaged in a spectrophotometric study with the microphotometer of coudé spectrograms of the Cepheid variables ζ Geminorum and η Aquilæ at different phases of light. Near minimum, both stars are difficult to photograph with such high dispersion, but considerable useful material has been collected.

INTENSITY OF LINES IN STELLAR SPECTRA

Dr. Russell has discussed the maxima of stellar lines in a sequence of stars of different temperatures, in which the atmospheric opacity arises from the presence of electrons and ions. The maximum of the lines of one element often depends mainly on the ionization of another. For example, an atmosphere composed exclusively of hydrogen would be so transparent at low temperatures, when the ionization is small, that the Balmer lines would strengthen with falling temperature. The presence of even a small proportion of metallic atoms, which remain ionized, would prevent this extreme transparency and produce the observed maximum in Class A. Again the ionization of the abundant hydrogen greatly increases the opacity and raises the photosphere in the hotter stars. This diminishes the intensity of the lines of Fe II and causes them to have a maximum in type F5, rather than at a much higher temperature. The observed effects indicate that the number of hydrogen atoms is of the order of a thousand times that of all the metals together.

A good approximation to the behavior of an actual stellar atmosphere is provided by one containing one atom of potassium for three of sodium, 12 of iron and 16,000 of hydrogen. With rising temperature, the ionization of one of these elements is nearly complete before that of the next begins, and the equations become tractable.

Detailed calculations have been made which take into account the variations of gravity with spectral type along the main sequence and among the normal giants. The resulting temperatures and spectral classes at which a number of important lines should be at maximum agree very closely with observation, excepting only the Balmer series and Mg II $\lambda 4481$, for which the predicted spectrum is F0 and the observed A2. This discrepancy may be attributed to distortion of the energy-curve of A stars by continuous hydrogen absorption beyond the limit of the Paschen series, which makes them too blue for their actual temperatures. Accepting this explanation, the problem of line-maxima appears to be satisfactorily solved.

The principal results of this work were reported in the Halley Lecture at Oxford on June 1, 1933.

LABORATORY INVESTIGATIONS

RARE-EARTH SPECTRA

King has completed the temperature classification of 2863 neodymium lines between $\lambda 2960$ and $\lambda 7000$, including the stronger enhanced lines and all but the faintest lines of neutral neodymium. New wave-lengths have been measured for 2026 lines. The results bring out the grouping of singly ionized lines of various levels, which are the lines of astrophysical interest. Many low-temperature lines have been found. The lines of the neutral atom seem in general to arise from two groups of closely associated energy levels.

The study of the spectrum of samarium has been extended into the infrared. A comparison of spectra from very pure preparations of neodymium and samarium for the detection of lines apparently common to both elements, which might belong to the intermediate element illinium, and the measurement of wave-lengths shows that in nearly all cases such lines either

are not exactly coincident or belong to the neutral spectrum of one element and to the ionized spectrum of the other. An interesting feature of the samarium spectrum is the large proportion of unsymmetrical doublets, occasionally resolved, especially in the long wave-length region. This hyper-fine structure for samarium indicates a nuclear momentum of $0.5 \hbar/\pi$.

INFRA-RED SPECTRA

On photographs of the iron spectrum made by King with the electric furnace at different temperatures, the material of the tube shows very strong bands of the CN molecule in the extreme red. These bands are degraded toward the red and, according to the analysis of the spectrum, arise from the same low level as the violet cyanogen bands. The furnace brings out the detailed structure of three bands with first heads at $\lambda\lambda 6910$, 7850 and 9107 , the last of which extends beyond $\lambda 10400$. A preliminary comparison by Merrill indicates that these bands account for much of the infra-red structure of N-type stellar spectra.

TEMPERATURE OF RADIATING BODIES

Thermocouple measurements of the transmission of a water cell or microscope cover-glass afford a simple means of estimating the temperature of a black body in the laboratory which avoids calibration against a standard of radiation. Tables have been constructed by Pettit and Miss Ware which give the temperature from 200° to $20,000^\circ$ K as a function of the transmissions, either with or without a silvered mirror in the optical path. The tables show that the water cell alone determines temperatures from 1500° to 7000° K, with or without the silvered mirror. The cover-glass transmission determines temperatures from 200° to 3000° K, and also from 6000° to $20,000^\circ$ K when there is no silver reflection. Measurements of the electric furnace with water cell and cover-glass give temperatures agreeing with those obtained by other methods.

A PHOTOMETRIC COMPUTING DEVICE

The usual methods for converting the microphotometer tracing of a spectral line into a true intensity-curve involve so much computation as to be almost prohibitive in an extensive program. Dunham has developed a device which eliminates all computation and gives the numerical result directly. An index mark connected with a lever, one end of which operates on a vertical steel band through a pair of rollers, is set on a point of the microphotometer contour under consideration. The steel band is held by clamps in the form of the photometric reduction-curve and is attached to a plate, free to slide along the axis of abscissæ, which carries the index of a logarithmic scale. This scale is set to read zero on the continuous background of the spectrum. It is then a simple matter to make settings at equally spaced intervals within the spectral line and to read directly the corresponding percentages of absorption, from which the true contour of the line may be plotted. The total absorption of the line is obtained by adding the individual readings and multiplying by a constant.

THE LARGE CONDENSER

Anderson has greatly improved the efficiency of the large condenser by reducing the inductance of all the electrical connections. Before these changes were made, the frequency of oscillation was 60,000 per second, while it is now possible to obtain 150,000. Since the maximum value of the discharge current varies directly with the frequency, a current 2.5 times the previous maximum value can now be obtained. A study of the vacuum spark spectrum of elements of especial astrophysical interest is in progress with this instrument.

ZEEMAN EFFECT FOR COBALT

Measurements of the Zeeman patterns of 280 cobalt lines between $\lambda 4100$ and $\lambda 6700$ in a field of 30,000 gauss have been made by King. No study of the magnetic resolution of cobalt lines in this region had previously been made. The data are needed for comparison with sun-spot lines and for the term analysis of the spectrum.

MISCELLANEOUS LABORATORY INVESTIGATIONS

Further experimental work by King has included special spectroscopic investigations of calcium, barium, erbium, titanium and columbium and studies of the ultra-violet spectrum of the sun with high dispersion.

Tests by Anderson of the chamber for the 10-foot vacuum spectrograph have shown that the large casting at the plateholder end is too porous to be satisfactory. With all leaks closed on the outside surface, two days are required to obtain a vacuum of 0.001 mm. owing to the diffusion into the chamber of gas filling the pores of the metal. A new casting of aluminum alloy will, it is hoped, remedy this defect.

Smith has constructed a new galvanometer primarily for use at the principal focus of the 60-inch telescope. It consists of the element of an instrument of the pointer type to which is attached a frame carrying a small quartz fiber. A microscope with an eyepiece scale is arranged for reading the position of the fiber, and the moving element is so balanced that the instrument may be tilted as much as 45° from the vertical without serious changes in the readings.

RULING MACHINES

A few gratings have been ruled by Babcock with the old machine, one of which, a 6-inch flat with 70,000 lines, shows high intensity in the second order and good resolving power. For the most part, however, the machine has been used for experimental work pending the replacement of defective parts. The diamond carriage has already been refitted to the ways and the driving mechanism improved.

The new smaller machine is now assembled in place, after having been tested by Babcock with a Michelson interferometer through the earlier stages of construction, and has been operated in a preliminary way. Some minor details remain to be completed, and the temperature control system is yet to be installed. The exacting problem of deducing the nature and origin of sources of error from imperfections in the trial rulings is now to be faced.

Prall, of the instrument shop, has given nearly all his time to the construction and adjustment of this machine.

The diamond cutting machine has been rebuilt, and diamond points can now be shaped to the proper angles for ruling without serious difficulty. Progress has also been made on the production of metal suitable for grating surfaces, both through direct experiment and through cooperation with the Committee on Ruled Gratings of the American Physical Society.

VELOCITY OF LIGHT

Measurements of the velocity of light with the vacuum pipe line at the Irvine Ranch were continued by Pease and Fred Pearson of the University of Chicago until August 4, 1932. With the aid of a special appropriation by the Carnegie Corporation, they were resumed on December 3 and continued until February 27, 1933. The entire series of measures, beginning in 1931 and made mostly between the hours of 7 and 9 p. m., show fluctuations which suggest a double variation, including a short period of $14\frac{3}{4}$ days and a long period of one year, with amplitudes in both cases of about 20 km./sec. The short-period fluctuation flattened out in December 1932 and the first half of January 1933, but seemed to reappear in February. The curve of variation resembles in many respects that of the tide-raising force, although there is no known way in which variations in this force can produce changes in the measured velocity of the magnitude observed. The direct effect on the period of the pendulum is negligible, and changes in the base line resulting from earth tides seem also to be excluded. A third independent measurement of the base by Lieutenant E. B. Latham of the United States Coast and Geodetic Survey, including 33 traverses made on 12 days in January and February 1933, shows no appreciable variation and confirms the earlier values. A definite correlation of measured velocity with tide-raising force would imply a diurnal variation in addition to the other periodic changes. Attempts to extend observations throughout the night have given a few suggestive results, but in the main are inconclusive because of bad definition of the image, which usually appears about 9 p. m. At present, therefore, the observed irregularities are unexplained and their elucidation apparently will require more sensitive apparatus, preferably of a type different from that thus far used.

In the meantime, Pease is engaged in the reductions of the observations in order to determine the most probable value of the velocity obtainable from the entire series of measurements.

CONSTRUCTION DIVISION

The severe snow and ice storm on Mount Wilson in January broke many trees and damaged greatly the roof of the large storage reservoir. The roof has since been replaced and the grounds have been thoroughly cleared of fallen brush. This work, as well as all the maintenance work on the buildings in Pasadena and on Mount Wilson, has been under the direction of A. N. Beebe. In August 1932, Beebe drove the motor truck carrying the eclipse apparatus throughout the long journey to Lancaster, New Hampshire, and return.

Alden F. Ayers has directed the work of the instrument shop, and E. C. Nichols, assisted by H. S. Kinney, has been in charge of design. The new ruling machine for diffraction gratings has been the principal instrument under construction. Other apparatus has included the mounting for the Ross correcting lens on the 100-inch telescope, the new base for the 75-foot spectrograph at the Solar Laboratory, additions to the photoelectric microphotometer, a motor-driven cover for the 60-inch telescope, the double-star interferometer, and much spectroscopic equipment. The bearings of many of the trucks carrying the dome of the 60-inch reflector have been replaced with ball bearings, and the driving clock on this instrument has been largely rebuilt.

John S. Dalton, assisted by D. O. Hendrix, has carried on the work of the optical shop. Many lenses, prisms and mirrors of different materials have been constructed, and the difficult task of figuring the 12-inch Ross correcting lens for the 100-inch telescope has been completed successfully by Dalton.

The continued operation of the instruments on Mount Wilson under the difficult conditions imposed by the great January storm and the breaking of the power transmission line was due largely to the skill and resourcefulness of Sidney R. Jones, engineer.

THE LIBRARY

During the year the library was increased by 332 volumes, 53 by gift, 78 by purchase, 201 by binding; the total number is now 12,271, with about 9000 pamphlets. In 1933 the library is receiving regularly 125 serial publications, of which 38 are by gift or exchange, and, in addition, the publications of about 200 observatories and research institutions.

NUTRITION LABORATORY¹

FRANCIS G. BENEDICT, DIRECTOR

One of the major problems of the Nutrition Laboratory in its twenty-five years of existence has been the study of the basal metabolism of humans. Incidental thereto, techniques have been developed that make possible not only rapid clinical measurements but also precise physiological measurements of metabolism. The application of these techniques has been widespread, and as a result the literature today contains numerous reports of basal metabolism measurements which, although made chiefly in pathological cases, include a goodly number on normal individuals that may serve as a physiological basis for comparative purposes. In America the use of basal metabolism measurements, particularly in studying border-line cases of endocrine disturbances, has been general. The wide distribution of the Nutrition Laboratory forms of basal metabolism apparatus in the United States indicates that the interest in basal metabolism in this country is almost universal. Indeed, hardly any well-established American hospital at the present time is without its metabolism section. Some idea of the extent of the distribution of these Nutrition Laboratory forms of apparatus may be derived from the fact that of the two principal manufacturers of these apparatus, one has sold over six thousand instruments and the other approximately twenty-five hundred in the United States.

On the Director's recent tour of university laboratories, hospitals and clinics in Europe the interest in basal metabolism measurements was found to differ greatly in the various countries. Perhaps the most astonishing fact noted was the almost complete dearth of metabolism measurements in Great Britain. In Germany this measurement is employed as an index of physiological normality far more frequently than in any other country in Europe, but it is surprising to find so relatively little hospital usage of such measurements in France and in most Scandinavian hospitals, in spite of the development in Scandinavia of the splendid Krogh apparatus. In Austria, in Hungary and in Yugoslavia there was also little use of this important physiological measurement. Since the modern methods call for a much more simplified apparatus than was formerly utilized, this absence of metabolism studies in certain parts of Europe can not be attributed solely to economic conditions but represents a real apathy toward what in America is considered an important hospital measurement.

The next logical step in American hospitals is to introduce basal metabolism measurements as a routine procedure in the admission of every patient to a hospital, comparable with measurements of heart rate and blood pressure and with urine analyses. To this end a respiration apparatus has been developed in the Nutrition Laboratory (see abstract No. 2, page 174, for published description of same) which makes possible basal metabolism measurements without demanding, as in the case of some of the other forms of respiration apparatus, the technical skill required for precise gas analysis.

¹ Situated in Boston, Massachusetts.

Although in the Nutrition Laboratory's metabolism studies primary emphasis has always been laid upon those problems dealing with humans, nevertheless during the current year substantial contributions have been made to the Laboratory's comprehensive program concerned with the comparative physiology of animals. At the moment of writing there are in progress investigations on the metabolism of the albino rat, the rabbit, the hibernating marmot or woodchuck, the pigeon and the dove, large domestic animals, and the primates, the *Macacus rhesus* and the chimpanzee. The perturbed metabolism of sick humans is often paralleled by the normal metabolism of some animal, and hence one can not stress too greatly the importance of a better understanding of the metabolism of various animals.

COOPERATING AND VISITING INVESTIGATORS

Professor E. G. Ritzman, of the Laboratory for Animal Nutrition at the University of New Hampshire, is continuing his comprehensive investigation in association with the Nutrition Laboratory on the physiology of large domestic animals. The admirable facilities provided by the University of New Hampshire, together with the solid support of President E. M. Lewis and Director John C. Kendall, have made this one of the most effective cooperative ventures of the Nutrition Laboratory.

Dr. Oscar Riddle, of the Department of Genetics of the Carnegie Institution of Washington, is actively furthering his studies on the basal metabolism of pigeons and doves in connection with his studies on genetics, endocrine glands and sex.

Dr. George L. Streeter, Director of the Department of Embryology of the Carnegie Institution of Washington, has contributed greatly to the success of the study of the *Macacus rhesus* in Dr. Carl Hartman's colony of these animals.

Professor H. C. Sherman, of the Department of Chemistry of Columbia University, New York City, has devoted a great deal of time to the planning of a cooperative study on the influence of old age upon metabolism, using his large rat colony and furthering his important observations on the influence of diet on longevity.

Professor Robert M. Yerkes, Director of the Anthropoid Experiment Station of Yale University, located at Orange Park, Florida, has for a number of years been in conference with the Nutrition Laboratory in regard to a proposed cooperative study of the physiology, especially the metabolism, of apes. In the Nutrition Laboratory's report of a year ago it was mentioned that plans for a study of the large chimpanzee colony of Dr. Yerkes were developing, and it is a pleasure to report that through his intense interest the program has been definitely launched.

Professor John F. Fulton, of the Department of Physiology of Yale University, has most enthusiastically aided in the planning and development of the research on the anthropoid apes.

The racial metabolism study to which the Nutrition Laboratory has been committed for a number of years has been continued actively, under conditions at times incredibly difficult. Adding to her already extensive collection of data on the metabolism of South Indian women, Professor Eleanor

D. Mason, of the Women's Christian College in Madras, has made this study her major research activity. In this work she has been heartily supported by Dr. Eleanor McDougall, Principal of the College. Professor Mason has recently arrived in Boston and is cooperating in the preparation of her material for publication.

Incredible though it may seem (owing to the difficulties occasioned by the political and economic situations in China), Dean Stanley D. Wilson, of the College of Natural Sciences, Yenching University, Peiping, China, has continued with unabated vigor his studies on the metabolism of Chinese from various quarters. His activity has been in large part in Peiping, but he is likewise including some of the outlying provinces.

Owing to the disturbed conditions, Professor L. G. Kilborn, of West China Union University, Chengtu, Szechwan, China, and Professor H. S. D. Garven, of Moukden Medical College, Moukden, Manchuria, have had to postpone further racial studies.

In Honolulu at the University of Hawaii, Professor Carey D. Miller, of the Department of Household Science, has collected several hundred observations on the basal metabolism of the numerous racial mixtures found in Hawaii.

Professor F. A. Hitchcock, of the Department of Physiology, Ohio State University, Columbus, Ohio, spent several weeks at the Nutrition Laboratory acquiring, under Dr. Carpenter's direction, the technique of gas analysis and the various methods of measuring the respiratory metabolism of animals and humans.

Dr. John M. Bruhn, of Yale University, also spent several weeks at the Laboratory under Dr. Carpenter's direction perfecting himself in the use of the gas-analysis apparatus and particularly the gaseous metabolism apparatus to be employed in the Nutrition Laboratory's cooperative study, with Professor Yerkes, of the chimpanzee.

LECTURES AND STAFF NOTES

On July 25, 1932, Dr. T. M. Carpenter lectured on "Metabolism of muscular exercise" before a group of summer school students in physiology at the Harvard Medical School. On September 3, 1932, he read a paper on "The effect of combinations of hexoses on the human respiratory exchange" at the meeting of the XIVth International Physiological Congress in Rome, Italy. On February 9 and 10, 1933, he lectured at Columbus, Ohio, before the Ohio State Chapter of the Society of Sigma Xi on "The development of methods for determining basal metabolism of mankind" and on "Problems in the determination of the basal metabolism of man and factors affecting it." On April 10, 1933, a paper was read before the American Physiological Society in Cincinnati, Ohio, by Dr. Carpenter on "The effect of muscular exercise on the disappearance of ethyl alcohol in man." On May 2, 1933, this same topic was discussed by him at a colloquium at the Harvard Medical School, and on May 13 he gave his annual lecture on basal metabolism to the first year medical students.

During his European tour in the fall and winter of 1932-1933 the Director lectured on forty occasions in various universities and hospitals on the latest techniques and findings of the Nutrition Laboratory. The topics

discussed were "The physiology of great tortoises and snakes and its relation to human physiology," "Basal metabolism in comparative physiology," and "Human basal metabolism in the light of recent studies." On April 20, 1933, he spoke at the American Philosophical Society meeting on "Human gaseous metabolism in atmospheres of pure oxygen" and on April 25 at the National Academy of Sciences in Washington, D. C., on "Human insensible perspiration as a laboratory and clinical measurement."

At the annual meeting of the Northeastern Section of the American Chemical Society on May 27, 1933, Dr. Carpenter was elected a Director of the Section.

At a meeting of the Council of the Massachusetts Medical Society on February 1, 1933, the Director was elected an associate Fellow of this society.

Dr. Carpenter acted as American representative on the "Committee for the Standardization of Certain Methods used in making Dietary Studies," which met in Rome, September 2-3, 1932, under the auspices of the Health Organization of the League of Nations.

The Director was given the honorary doctorate in medicine on the occasion of the 350th anniversary of the University of Würzburg, Germany.

INVESTIGATIONS IN PROGRESS

On a recent tour of Europe it was observed that no feature of the Director's annual reports is more appreciated, in European centers at least, than the statement regarding investigations in progress. This method of listing material actually in hand and under experimental treatment is not commonly employed by European investigators. Examination of the Nutrition Laboratory reports for the past twenty-five years will show that the investigations noted have always been actively under way and that the results have usually been published within a year or two after the announcement, for the first time, under the heading of "investigations in progress."

Gas analysis—Through cooperation with the manufacturers, burettes have been made for the Carpenter gas-analysis apparatus that do not require correction of readings. This improvement will result in saving of time and diminution of chances of error in calculation of results.

Composition of urine of hibernating and fasting woodchucks—The urines of four hibernating and fasting woodchucks were collected for periods of about 3 months and analyzed for total nitrogen, creatine and creatinine, urea, ammonia, amino acids, total sulphur and phosphorus. The analyses were made by Miss M. Burdett, under Dr. Carpenter's supervision.

Influence of ingestion of sugars on the respiratory exchange of rats—In continuation of the research on the biological variations in the respiratory exchange after the ingestion of sugars, forty experiments have been made with adult albino rats on the effect of glucose, fructose and galactose on the gaseous exchange, with particular reference to the changes in the respiratory quotient in short periods. The measurements were made under Dr. Carpenter's direction by R. C. Lee, with the assistance of G. Lee and Miss M. Burdett.

The metabolism of ethyl alcohol and sugars—The study on the effect of muscular work upon the metabolism of alcohol, mentioned in last year's report, led to the striking conclusion that the metabolism of alcohol is not affected by muscular activity. To obtain further information on the mechanism of the metabolism of alcohol, Dr. Carpenter has started experiments with a human subject in which determinations are being made on the effect of the ingestion of alcohol in various quantities and dilutions on the respiratory exchange, the alveolar air, alcohol in expired air and alcohol in urine. It is planned to combine these same quantities of alcohol with sugars, to study the effect of the level of carbohydrate metabolism on the metabolism of alcohol. R. C. Lee is conducting the experiments, with the assistance of G. Lee and Miss M. Burdett.

Basal metabolism of geese—Although several hundred observations have been made upon this bird at the Nutrition Laboratory, extremely low values for heat production have occasionally been noted, and attempts have been made to find the special conditions under which these values could be reproduced. Both respiration and calorimeter experiments are still being made, by E. L. Fox and V. Coropatchinsky.

Physiology of the woodchuck—As a result of the Nutrition Laboratory's extensive measurements on warm-blooded and cold-blooded animals, the importance of studying carefully animals that may be stated to occupy an intermediate position is obvious. A special research has been in progress on a number of woodchucks, all of which fortunately went into hibernation. Studies have been made of the metabolism during the day compared with that during the night, the effects of various environmental temperatures, the metabolism during complete hibernation as compared with that when the animals were awake, the effect of starvation until death ensued and the course of the respiratory quotient after fasting. Accurate measurements were made of the respiratory exchange, the rectal temperature, the water of vaporization and frequently the insensible perspiration. The experiments were carried out by E. L. Fox, with the cooperation of V. Coropatchinsky and B. James.

Metabolism of the rabbit—Owing to its heavy fur and particularly its relatively large ears, the surface area of the rabbit presents an unusually interesting problem from the standpoint of heat loss. In the studies of earlier investigators on animal metabolism, many observations were made on the rabbit and debatable conclusions were drawn. Fortunately Professor W. E. Castle, of the Bussey Institution, has placed at our disposal a number of animals from his large rabbit colony, and for some time daily observations on the gaseous exchange, the rectal and skin temperatures, and the insensible perspiration of the rabbit have been made by E. L. Fox.

*Metabolism of the *Macacus rhesus**—Mr. Karl Koudelka was thoroughly trained in the technique of gas analysis by Dr. Carpenter and has subsequently continued at Baltimore the daily metabolism observations on the animals in Dr. Hartman's colony. It is believed that ultimately the results of the observations on the *Macacus rhesus* can be applied to the study of the chimpanzee.

Metabolism of pigeons and doves—A more intelligent use of metabolism technique in studying problems in endocrinology, genetics and sex can hardly

be found than that being made by Dr. Oscar Riddle, at the Department of Genetics of the Carnegie Institution of Washington. With two multiple-chamber respiration apparatus, eight birds are measured each night at different environmental temperatures and under various other conditions. Emphasis has been laid in recent studies on the metabolism of free-flying homing pigeons with reference to their excessive muscular activity in long flights, the metabolism of doves and pigeons in old age, the influence of sex in tippler pigeons during adolescence, that is, before ovulation begins in the case of the females, and the metabolism of one particular race of pigeons that produces three types of individuals—normals, ataxics and “scragglies.” The two latter kinds differ from the normals presumably by a single genetic feature. The measurements are being made by Mrs. G. C. Smith.

Metabolism of large domestic animals—In cooperation with the Laboratory for Animal Nutrition of the University of New Hampshire, under the direction of Professor E. G. Ritzman, the Nutrition Laboratory has continued its observations on domestic animals. During the year four metabolism experiments, each of five days' duration, were carried out with two horses, the primary object being to determine seasonal effects. One experiment of four days' duration was made with two young Berkshire sows, nearly full grown and weighing 133 kilograms each. Their metabolism was measured, first during two complete days while they were fed regularly and again during the fourth and fifth days of fasting. The observations on dry cows have been continued, and a preliminary attempt has also been made to study the energy requirements of the lactating cow. Other problems under investigation are the relative differences in the energy requirements for maintenance of the Holstein and the Jersey breeds, the differences in individuals of the same breed, the increase in metabolism due to lactation, the comparative effect on heat production of maintenance on ordinary grass hay with a low protein content and legume hay, such as alfalfa and soy bean hay, having a high protein content. Fourteen metabolism experiments, each of four days' duration, were carried out on five different cows. In this work Professor Ritzman has been most ably aided by Mrs. H. H. Latimer and Messrs. A. D. Littlehale, N. F. Colovos, and L. E. Washburn. In addition to the work at Durham, a number of tests have been made by V. Coropatchinsky at the Nutrition Laboratory, dealing with the aliquoting of air samples from large respiration chambers and particularly an electric hygrometer for use in the proposed determination of the total water vaporized by these large animals.

Maya foods—In the larger program of the Carnegie Institution of Washington of studying Middle American archæology with special reference to the Maya in Yucatan, the food habits of the natives that reflect earlier, inherited food traditions are of interest. A study was therefore begun of the present-day food habits of the Maya. In so far as possible, the study was confined to the foods of those individuals least affected by modern methods of living and least acquainted with canned food products. The food samples were collected by Dr. Morris Steggerda, sent to Boston, and there analyzed by E. L. Fox.

Studies in human basal metabolism—The Nutrition Laboratory feels obligated to make its investigations, in so far as possible, on humans, since

observations on animals are ultimately of greatest value only in the light of the information they contribute regarding the physiology of humans. Three major studies in the field of human basal metabolism were carried out in the past year. One of them dealt with the metabolism during sleep as compared with that during the state of being awake. Three of the laboratory staff members served as subjects for the beginning of this important research. Additional information regarding the influence of age upon metabolism was obtained by further observations on three subjects who had already been measured at the Nutrition Laboratory over a period of twenty-five years. The Laboratory purposes securing observations on each of these individuals in succeeding years. A year ago a research was begun to note the day-to-day variations in the basal metabolism of an individual thoroughly accustomed to metabolism measurements. The success of the preliminary observations led to a slight betterment in the technique and the experimental plan, and in the spring of 1933 the same subject was studied over a period of 33 consecutive days. These studies on humans were made by E. L. Fox, assisted by B. James.

EDITORIAL WORK

As usual, a large number of manuscripts have been completed and accepted for publication, advantage being taken of the Director's absence in Europe to concentrate upon the editing of such material. Although the rough draft manuscripts of the Director were prepared prior to his tour, their completion and editorial revision were exclusively in the hands of Miss Elsie A. Wilson, editor of the Nutrition Laboratory. Manuscripts that have been completed and accepted for publication are:

Some considerations on precise analysis of air from respiration chambers. (T. M. Carpenter. *Journal of Biological Chemistry*.)

The use of a pump as a gas sampler. (R. C. Lee. *Indus. and Eng. Chem.*)

The development of methods for determining basal metabolism of mankind. (T. M. Carpenter. *Ohio Journal of Science*.)

Problems in the determination of the basal metabolism of man and factors affecting it. (T. M. Carpenter. *Ohio Journal of Science*.)

Die Messung des unmerklichen Gewichtsverlustes beim Menschen in Laboratorium und Klinik. (F. G. Benedict. *Zeitschr. f. d. ges. exp. Med.*)

Studies on the physiology of reproduction in birds. XXXIII. Basal metabolism and the temperature factor in brooding ring doves. (O. Riddle and F. G. Benedict. *Amer. Jour. Physiol.*)

Probleme über die Oberflächenbestimmung verschiedener Tiergattungen. (F. G. Benedict. *Pflüger's Arch. f. d. ges. Physiol.*)

The influence of previous exercise upon the metabolism, the rectal temperature, and the body composition of the rat. (K. Horst, L. B. Mendel, and F. G. Benedict. *Journal of Nutrition*.)

The effects of some external factors upon the metabolism of the rat. (K. Horst, L. B. Mendel, and F. G. Benedict. *Journal of Nutrition*.)

Mental effort in relation to gaseous exchange, heart rate, and mechanics of respiration. (F. G. Benedict and C. G. Benedict. *Carnegie Inst. Wash. Pub. No. 446*. In press.)

In addition, the following manuscripts have been completely edited:

Techniques for measuring the total metabolism and especially the energy requirements of farm live stock (F. G. Benedict, V. Coropatchinsky, and E. G. Ritzman.)

Two electrically compensated emission calorimeters for small animals and infants and for adult humans. (F. G. Benedict.)

Surface area in a monkey, *Macacus rhesus*. (M. O. Lee and E. L. Fox.)

Influence of previous diet, growth, and age upon the metabolism of the rat. (K. Horst, L. B. Mendel, and F. G. Benedict.)

PUBLICATIONS

- (1) *Ein Apparat zur Analyse von Gasen aus Respirationskammern für Menschen und Tiere*. Thorne M. Carpenter. Abderhalden's Handb. d. biolog. Arbeitsmethoden, Abt. IV, Teil 13, pages 593-618 (1933).

The Carpenter gas-analysis apparatus is described in its latest form, including the modification for methane determinations. This apparatus can be used in all gaseous exchange studies when an open-circuit respiration apparatus is employed and when the outcoming air to be sampled for analysis has a carbon-dioxide content not exceeding 1.7 per cent and an oxygen deficit corresponding to the values found with respiratory quotients between 0.67 and 1.50.

- (2) *Der Helm-Respirationsapparat in seinen verschiedenen Formen*. Francis G. Benedict. Abderhalden's Handb. d. biolog. Arbeitsmethoden, Abt. IV, Teil 13, pages 465-524 (1933).

Details are given of the use of a helmet or head chamber connected with ventilation systems on the closed- and the open-circuit principles, to measure the carbon-dioxide production alone, the oxygen consumption alone, or both the carbon-dioxide production and the oxygen consumption. The helmet respiration apparatus is adaptable not only for experiments during rest but also during severe muscular work. On the open-circuit principle it is used in conjunction with the Carpenter gas-analysis apparatus. A combination of the helmet with closed ventilation circuit and a flow meter or "rotamesser" is recommended for the rapid approximation of basal metabolism in the general routine of admission of patients to hospitals or clinics.

- (3) *The effect of small quantities of galactose on the human respiratory exchange*. Thorne M. Carpenter and Robert C. Lee. Amer. Jour. Physiol., vol. 102, pages 635-645 (1932).

Ingestion of 5 to 40 grams of galactose caused in all cases an increase in the respiratory quotient, but during the latter part of the 2½ hours after the ingestion the quotient fell to below the pre-ingestion level. The increase in the apparent carbohydrate combustion represented from 13 to 32 per cent of the amount ingested. The maximum increase in heat production over the baseline in a 15-minute period varied from 10 per cent with 10 grams to 18 per cent with 40 grams. The specific dynamic action (increase in heat production referred to heat of combustion of the sugar) varied from 3 to 8 per cent. Galactose resembles fructose in its effects on the respiratory quotient and carbohydrate combustion and glucose in its effects on heat production.

- (4) *A comparison of the respiratory exchange of men and women as affected by the ingestion of galactose.* Thorne M. Carpenter and Robert C. Lee. Amer. Jour. Physiol., vol. 102, pages 646-658 (1932).

With four men and four women the maximum increase in the respiratory quotient averaged 0.11 in the third quarter hour after the ingestion of 20 grams of galactose. After 30 grams the average maximum rise was 0.16 and 0.17 with the men and the women, respectively, in the third or fourth quarter hours. Four out of five women, however, had a maximum rise of 0.19 or over. The apparent combustion of carbohydrate increased on the average 4 grams with both sexes after 20 grams of the sugar, and 9.9 grams (men) and 7.8 (women) after 30 grams of the sugar. The heat production of the men increased 1.9 calories after 20 grams and 9.7 calories after 30 grams, and that of the women 5.4 and 5.7 calories, respectively. The individual variations in all the factors were much greater with the women than with the men.

- (5) *A comparison of the effects on the human respiratory exchange of hexoses ingested separately and together.* Thorne M. Carpenter and Robert C. Lee. Amer. Jour. Physiol., vol. 102, pages 659-672 (1932).

With an adult man ingestion of 20 grams each of glucose, fructose, and galactose in combinations of two sugars produced practically the same increases in the respiratory quotient and in the combustion of carbohydrates as would be found by the addition of their effects when ingested separately. Forty grams of lactose caused slightly smaller rises in the quotient than 20 grams each of glucose and of galactose given together, but the return to the pre-ingestion values was not so rapid with lactose. The increase in the carbohydrate combustion after ingestion of 40 grams of lactose was essentially the same as when the two sugars equal to the hydrolysis products were given together. When 20 grams each of glucose and of fructose were taken together, the increase in heat production equalled the summation of the effects of these two sugars ingested separately, but when galactose was combined with either of these sugars there was a greater increase in heat production than would be expected from the summation of the effects of galactose and any other sugar given separately. Thus the qualitative reactions following the ingestion of hexoses were the same whether these were given separately or together, but some other factor than the changes in transformations of the carbohydrates played a rôle in bringing about the increases in heat production when galactose was ingested with some other sugar.

- (6) *The parallel determination of the respiratory quotient and alveolar air of man in the post-absorptive condition.* Thorne M. Carpenter and Robert C. Lee. Journal of Nutrition, vol. 6, pages 37-53 (1933).

The respiratory exchange of two men, sitting, post-absorptive, was measured in four and then ten consecutive 15-minute periods on three and four days, respectively, and samples of alveolar air were collected every 15 minutes without interrupting the respiratory exchange measurements. With the subject well trained in the use of respiratory appliances the average respiratory quotient and the alveolar carbon dioxide did not change significantly during 3½ hours, but with the untrained subject both factors varied, usually in opposite directions. The alveolar respiratory quotients of both men tended to run parallel with the respiratory quotients of the total expired air. Tendency to an inverse relationship between the alveolar carbon dioxide and the alveolar respiratory quotients was noted. There was a marked negative correlation between the alveolar respiratory quotient and the percentage alveolar oxygen deficit.

- (7) *The effect of glucose and of fructose on the human respiratory quotient and alveolar air.* Thorne M. Carpenter and Robert C. Lee. *Journal of Nutrition*, vol. 6, pages 55-82 (1933).

With a trained subject, the increases in the respiratory quotient after ingestion of 20 grams of glucose or of fructose were not accompanied by changes in alveolar carbon dioxide, but with an untrained subject the alveolar carbon dioxide decreased markedly during the periods of maximum rise in the respiratory quotient. In all experiments with both subjects, the correlation between alveolar oxygen deficit and alveolar respiratory quotient was markedly negative. In the experiments with glucose, one subject showed a maximum rise in the respiratory quotient of 0.065 and the other of 0.10. When the respiratory quotient of the untrained subject after ingestion of glucose was corrected for the rise in respiratory quotient corresponding to the falls in alveolar carbon dioxide equivalent to those occurring after ingestion of glucose, the net increase in the respiratory quotient was the same as with the trained subject. The maximum increase in the respiratory quotient of expired air in the fructose experiments with the trained subject averaged 0.11. With the untrained subject the average maximum increase in this factor was 0.16, and there was a decrease in alveolar carbon dioxide of 0.4 per cent. When the respiratory quotient of expired air is corrected for the apparent rise due to the decrease in alveolar carbon dioxide found in previous post-absorptive experiments with this subject, the increase in the respiratory quotient of the expired air becomes 0.12 or practically the same as with the trained subject. If the constancy of the alveolar air indicates the true metabolic respiratory quotients, the net rise in respiratory quotients in these experiments following ingestion of fructose must be considered the result of the metabolism of fructose without the formation of organic acids in its transformation in sufficient quantities to affect the carbon-dioxide tension of the alveolar air.

- (8) *The influence of glucose and of fructose on the effective dead space in human respiration.* Thorne M. Carpenter and Robert C. Lee. *Amer. Jour. Physiol.*, vol. 101, pages 10-17 (1933).

The effective dead space in breathing at rest was studied with a trained subject before (post-absorptive) and after the ingestion of 25 grams of glucose or fructose. The carbon-dioxide dead space averaged 47 per cent of the volume per respiration and did not vary widely in the different experiments. The oxygen dead space averaged much the same and showed about the same range of variations. Calculation of the alveolar carbon dioxide by use of a constant percentage of the volume per respiration as dead space resulted in values agreeing more consistently with the directly determined values than with those calculated by use of a constant volume of dead space.

- (9) *The effect of muscular exercise on the metabolism of ethyl alcohol.* Thorne M. Carpenter. *Journal of Nutrition*, vol. 6, pages 205-224 (1933).

An editorial review of the principal investigations on the effect of muscular activity on the metabolism of alcohol in man and animals.

- (10) *The physiology of normal and frizzle fowl, with special reference to the basal metabolism.* Francis G. Benedict, Walter Landauer and Edward L. Fox. *Storrs Agric. Expt. Sta., Bull.* 177, April 1932, pages 13-101.

Between 15° and 28° C. changes in environmental temperature did not affect the metabolism of normal fowl (*Gallus domesticus*). At night the

metabolism was much lower than during the day. Measurements at night are therefore alone of value in basal metabolism considerations with fowl. Normal moulting hens had a higher metabolism than normal non-moulting hens. With the Frizzles (F_1 -Frizzle, exhibition-type Frizzle, and homozygous Frizzle), both at 28° and 17° C., the fasting heat production was greater than that of normal fowl and nearly in proportion to the defective nature of the plumage. The metabolism of the homozygous Frizzles increased about 4 per cent for each degree decrease in environmental temperature between 28° and 17° C. The rectal temperatures of all the fowl were between 41° and 42° C. There was no pronounced difference ascribable to length of fasting up to 72 hours, to environmental temperature down to as low as 15° C., to sex, or to condition of plumage. At environmental temperatures below 15° the homozygous Frizzles had subnormal rectal temperatures. The surface temperatures of the wattles, comb, ear lobe and legs and on the breast and back were with all the birds, both under fasting conditions and with food and irrespective of condition of plumage, higher than the environmental temperature and tended to increase as the environment became warmer. At environmental temperatures of 28° to 30° and 17° to 19° the proportion of the total heat production lost in the vaporization of water amounted to 49 per cent with the normal fowl and to 17 per cent with the Frizzles.

- (11) *The heat production of unusually large rats during prolonged fasting.* Francis G. Benedict, Kathryn Horst and Lafayette B. Mendel. *Journal of Nutrition*, vol. 5, pages 581-597 (1932).

Two male albino rats (822 and 730 grams) fasted 57 and 38 days, respectively, and lost 46 and 55 per cent of their initial weights. The total oxygen consumption decreased until about the twentieth day of the fasts, but thereafter remained relatively constant. The heat production per unit of weight and per unit of surface area decreased markedly during the first few days, but toward the end of the fasts increased. There was no increase in cell temperature or in activity to account for this increase in metabolism. Comparison of the basal metabolism of these two unusually large rats with smaller rats indicated that the metabolism was lower per unit of weight and per unit of surface area, the larger the rat. The rectal temperatures of the very large rats were similar to the body temperatures of medium-sized and large-sized rats.

- (12) *Der Energieumsatz normaler und haarloser Mäuse bei verschiedener Umgebungstemperatur.* Francis G. Benedict and Edward L. Fox. *Pflüger's Arch. f. d. ges. Physiol.*, vol. 231, pages 455-482 (1933).

Normal laboratory-bred mice, 17 hours without food and with minimum activity, had a heat production averaging 640 calories per square meter of body surface per 24 hours at 28.5° and of 935 calories at 15.7° C. The increase in metabolism per degree decrease in temperature was 3.6 per cent. The metabolism was higher at 32° than at 28° C. Huddling had no effect. In isolated periods with mice (quiet and post-absorptive) that had been living at 28° C. for many hours, values of 500 calories and in other instances of 400 calories were noted. The wide range in the values at thermic neutrality is ascribable to the almost incessant activity of the mouse, which makes for a high metabolism, and the tendency at times for subnormal body temperatures, which would be accompanied by a low metabolism. Apparently the basal heat production of the mouse approximates 500 calories. The temperature of thermic neutrality for hairless mice was 34° C., at

which the basal metabolism averaged 750 calories per square meter. At 28° it was about 1000 calories and at 16° three times that at 34° C.

- (13) *The oxygen consumption of fasting white mice.* J. E. Davis and H. B. van Dyke. Jour. Biol. Chem., vol. 100, pages 455-462 (1933).

Male albino mice studied at the University of Chicago were found to have an oxygen consumption at 28° and 17 to 24 hours after food averaging 38.5 liters per kilogram of body weight per 24 hours, when they were in the quiet, relaxed state. These same mice, studied at the Nutrition Laboratory by a different technique, under the same conditions of temperature, degree of repose and fasting, had an oxygen consumption of 40.0 liters. The Chicago investigators reported an oxygen consumption of but 28.3 liters when the mice were sleeping. Values as low as this were found later in the Nutrition Laboratory on a different group of mice, each of which, after being without food from 18 to 43 hours, showed a lowering of rectal temperature of from 1.6° to 3.5° C. A somewhat smaller lowering of rectal temperature was also noted in the Chicago laboratory on mice that had been without food 17 to 24 hours. This lowering of temperature of mice under the conditions observed may in large part explain the comparatively low metabolism.

- (14) *Der Grundumsatz von kleinen Vögeln (Spatzen, Kanarienvögeln, und Sittichen).* Francis G. Benedict and Edward L. Fox. Pflüger's Arch. f. d. ges. Physiol., vol. 232, pages 357-388 (1933).

Observations on canaries, parrakeets, wild English sparrows, and one song sparrow indicated that it is impracticable to make basal metabolism measurements before 6 or 7 p.m., as the metabolism is higher during the daytime. Huddling apparently had no effect. Within the zone of thermic neutrality the male canaries had a somewhat higher metabolism than the females. At 16° and below, apparently whatever sex difference exists is small and is obscured by the temperature effect. The basal metabolism of canaries and parrakeets (at night, with minimum activity, and 10 hours after food) averaged 718 calories per square meter of body surface per 24 hours at thermic neutrality and 1077 calories at 16° C. Under similar conditions wild English sparrows had a heat production of 656 calories at thermic neutrality and 914 calories at 16° C. Contrary to previous conceptions, therefore, these small birds with a high cell temperature (about 42° C.) have an unusually low metabolism.

- (15) *The basal metabolism of American-born Chinese girls.* Francis G. Benedict and Mary Henderson Meyer. Chinese Jour. Physiol., vol. 7, pages 45-60 (1933).

The basal metabolism of eighteen American-born Chinese girls (12 to 22 years old) living in the United States was, on the average, 9 per cent below the standards for American Girl Scouts of the same age and 6 per cent below the Aub and Du Bois standards for American girls in this age range. The pulse rates were somewhat lower than those observed with American girls. The Chinese girls were normal and in no sense undernourished.

- (16) *Le métabolisme de base chez les différentes races.* Francis G. Benedict. Biotypologie, March 1933. 5 pages.

Résumé of a communication presented on February 6, 1933, at a meeting of the Société de Biotypologie in Paris.

DIVISION OF PLANT BIOLOGY¹

H. A. SPOEHR, CHAIRMAN

The Division has been most fortunate in having been able to maintain the most important of its research projects during the economic stress of the past few years. This applies particularly to those projects in which valuable collections of living material are involved; final results from these investigations might be greatly affected or permanently lost through a serious interruption in their continuity. Conditions are making necessary the examination of all research projects as to their real scientific significance and the careful scrutiny of the mode of operation and methods employed to achieve the desired aims. Difficult as these adjustments are, if they are not too sudden, they may not be without their compensation in helping to clarify the problems under investigation.

Both the laboratory and garden facilities of the Central Station of the Division are proving highly satisfactory. The perennial gardens were entirely replanted on the basis of an improved system of records. These are now planted by genera, each of which is arranged systematically and geographically so that the plants tell their own story. The experimental gardens at Mather and on the crest of the Sierra Nevada have also been rearranged and are yielding interesting results.

The formation of rings in trees through the periodic accretion of wood material has engaged the attention of plant physiologists for a great many years. The realization of the extreme complexity of this phenomenon has made clear the fact that advance in this field is dependent upon the closer cooperation of experts in various scientific disciplines which can be applied to these problems. During the past year a step in this direction has been taken through a union of anatomical and chemical investigations of wood. The researches of Dr. I. W. Bailey of the Bussey Institution of Harvard University have already contributed greatly to an elucidation of the function of the cambium tissue by which both wood and bark are formed. Since the organization of the Central Laboratory of the Division, Dr. Bailey has spent a portion of each year there in the pursuit of his investigations. It has become apparent that an understanding of the phenomena associated with the growth and differentiation of the various structures within the tree, of the translocation of organic substances and of the movement of liquids and gases depends upon detailed and reliable information concerning the cytology of the living cambium and its differentiated derivatives. These tissues are composed of a variety of extremely complex organic substances—cellulose, hemicellulose, lignin, pectic substances, etc.—for the detection of which accurate micro-chemical methods must be developed. Obviously the solution of this problem depends upon reliable information concerning the chemistry of wood. During a portion of the past year, Dr. Ernest Anderson of the University of Arizona, who has been investigating the chemical structure of hemicelluloses and related substances, has been carrying on a cooperative investigation with Dr. Bailey directed toward the extraction and analysis

¹ The Central Laboratory of this Division is located at Stanford University, California.

of the various constituents of wood and the determination of their exact chemical constitution with a view to determining as far as possible the inter-conversion of these complex substances in the course of the development of the tree.

Continuing his distributional studies of the Tertiary floras of the Pacific Basin, Dr. R. W. Chaney spent the period from May first to July eleventh in northeastern Asia. Fossil plants from several localities in China and Manchukuo show a close resemblance to those from corresponding horizons in western America and emphasize the extent of interchange of vegetation between Asia and North America during later geologic time. The deciduous elements of the modern forest in the mountains of Chosen and northern Japan are more similar to the middle Tertiary floras of western America than any forests now living on this continent; a brief study of them has added greatly to our knowledge of the conditions under which these fossil floras lived. From the Pleistocene deposits at Choukoutien, Dr. Chaney secured a few specimens of plants which lived in this part of China at the same time as *Sianthropus pekingensis*, the oldest known human inhabitant of Asia.

In conjunction with his formulation of the program of investigation in experimental taxonomy, Dr. H. M. Hall had for a number of years been working on plans for reserving certain areas of land with as little disturbance of primitive conditions as possible for purposes of scientific research. Through the cooperation of the United States Forest Service, a small transplant station was operated in the Mono National Forest in the Sierra Nevada at an elevation of about 10,000 feet. The opportunity thus offered of thoroughly examining this region resulted in the decision that this area presented an unusually interesting complex of environmental conditions and of biological material. It extends in altitude from about 9800 feet to 12,556 feet at the summit of Mount Conness, is bounded on the south by a wild life reserve within Yosemite National Park and comprises about 7 square miles. It includes the subalpine and alpine life-zones, with numerous types of vegetation represented. The varied topography with rock-slopes, glaciers, cirques and small lakes presents highly diversified conditions of biological interest as well as an unusually beautiful primitive landscape. Just prior to his death, Dr. Hall, with the active support of Dr. Merriam, started negotiations with the Forest Service for reserving this area for the exclusive purposes of scientific research. During the past year a cooperative agreement has been entered into between the Carnegie Institution of Washington and the Forest Service which makes the area available for these purposes and assures retention of the primitive conditions. The area has been designated by the Forest Service as the Harvey Monroe Hall Natural Area.

The Division has acquired a portion of Dr. H. M. Hall's library, which contains a number of books of exceptional value and interest in connection with the program for the continuance of the researches in experimental taxonomy. An extensive series of separates dealing with this subject is also included. These publications have been incorporated in the library of the Central Station and have been marked with a special book-plate.

Dr. John Belling died of heart disease in Berkeley, California, on February 28, 1933. For a number of years Dr. Belling had been associated with the

Department of Genetics, in Cold Spring Harbor, but, as he had suffered from ill health, an arrangement was made with the University of California which provided him with a private laboratory in the Division of Genetics of that institution. When the Division of Plant Biology of the Carnegie Institution was organized, he became one of its staff members but continued his work in Berkeley. Endowed with an unusually keen mind and the master of a highly refined technique, his life, to the last day, was devoted to the investigation of some of the most fundamental problems of cytology. To the clarification of these, particularly in their relation to genetics, he has made notable contributions.

PHOTOSYNTHESIS

LEAF PIGMENTS

When the program for investigation of the yellow leaf pigments was inaugurated, the opinion prevailed that the great majority of terrestrial plants contained but two of these pigments, carotene and xanthophyll. The unexpected physiological significance which it was found that these substances possess has greatly stimulated research in this field, both in this country and abroad. This has resulted in the discovery that there are two, and possibly more, distinct isomeric forms of carotene. These isomeres possess slight, though important, differences in their physical properties. The object of the present research program has been the determination of the structure of the carotene molecule. For this purpose it is essential to have chemically homogeneous compounds. It has, therefore, become necessary to develop methods for the separation of mixtures of the different forms of carotene, to prepare the pure compounds and to establish criteria on the basis of which the different isomeric forms can be definitely identified and the presence of mixtures can be detected.

Two general methods have been employed to obtain the different forms of carotene in a pure state. The first of these is the extraction of carotene from such plants as contain but a single form. The other method is the separation or resolution into its components of mixtures of the different forms of carotene such as are obtained from some plant sources, notably carrot roots. The two principal forms have been designated as α -carotene, characterized by its optical activity, and β -carotene, which is optically inactive. The carotene which has been prepared in this laboratory from leaf sources, *viz.*, sunflower, sugar-beet, spinach, alfalfa, chard and cauliflower, has all been found to be of the optically inactive form, although leaf sources for optically active carotene have been found by other workers, one in Germany and one in Japan.

Dr. Smith has succeeded in isolating a highly purified preparation of α -carotene from the carotene mixture obtained from carrots. This carotene mixture, dissolved in petroleum ether, was partially adsorbed on fullers' earth, the optically inactive form being preferentially adsorbed. By repeating the process successively with the unadsorbed portion, a product was finally obtained which was highly dextro-rotatory. The physical properties of this material indicate that it was purer than any other optically active

carotene previously obtained. However, the yield was exceedingly low. Dr. Strain has made an exhaustive study of adsorbents and solvents for use in this method of separating the isomeric carotenes from mixtures. He has been able to prepare an active adsorbent from a mixture of "norit" and siliceous earth. This is activated by heating it to 500° C. in a vacuum and then allowing it to cool in an atmosphere of nitrogen or carbon dioxide. The carotene mixture, dissolved in dichloromethane, is passed through a column of this adsorbent. The optically inactive carotene is adsorbed and the effluent contains the optically active form. Thus, for example, a carotene mixture having an optical rotation of $[\alpha]_{6678} = +80^{\circ}$ after one adsorption yielded carotene with $[\alpha]_{6678} = +352^{\circ}$. It has also been possible to recover the adsorbed carotene in fair yields by washing the adsorbent with pyridene. This method of separation has not as yet been perfected and a variety of adsorbents and solvents are still under investigation.

Thus far no chemical properties of carotene have been discovered on the basis of which the various isomeres can be easily and definitely identified. Dr. Smith has, therefore, endeavored to establish criteria for the identification of the specific forms of carotene and to determine the relationships which exist between them on the basis of certain of their physical properties. For this purpose he has made an extensive study of the melting points, optical rotation, absorption spectra and solubility of the pure forms and of mixtures. The melting points of highly purified samples of the various leaf carotenes already mentioned varied from 178° to 182° . Mixing and recrystallizing of these carotenes produced no appreciable lowering of the melting points. It would appear, therefore, that they were identical or formed perfect solid solutions. Similarly, the specific optical rotations of all the leaf carotenes were found to be zero. The optical rotation of carrot root carotene has always been found to be dextro-rotatory. The previously reported levo-rotation was in error. This error was caused by a shift in the zero point produced by change in the wave length of the light transmitted by the colored carotene solutions. The new polarimetric equipment in which the helium line $\lambda = 6678$ is used as a source of light obviates this difficulty.

Of considerable practical aid in identifying preparations of carotene obtained from various sources have been the phase rule data which have been worked out with a number of highly purified preparations of carotene. This is based upon the well-known principle that if only two constituents are present in a mixture, a regularity exists between any two physical properties, while if more than two constituents are present irregularities in the observed properties will become evident. Thus, when melting points of samples of carrot root carotene are plotted against the specific rotations, a diagram is obtained which is typical of a two-component system in which solid solutions but no compounds are formed. At the same time some deviations from the average curve have been observed which indicate the presence of more than two components and to which as yet it has not been possible to give an adequate explanation. The absorption spectra of carotenes from various sources have been subjected to more careful study by Dr. Smith and Mr. Milner. This is probably the most interesting and characteristic property of these compounds, although the interpretation of the absorption spectra data offers

a number of complex problems which have as yet not been solved. While the absorption spectra of all of the leaf carotenes thus far examined are very similar, they are not identical. Even carotene preparations from the same species of leaves, *e.g.* chard, exhibit appreciable differences in absorption spectra, indicating possibly that there are differences here which can not be detected in any other way. Aside from these minor deviations the absorption spectra constitute a most useful aid in identifying the different forms of carotene. The most highly purified preparation of α -carotene was found to possess an absorption maximum which lies about 70 Å. toward the violet from the corresponding mean maxima of the leaf carotenes.

Some measurements of solubility of carotene in various organic solvents and the correlation of these determinations with other physical properties have also been made. This method is promising of useful information concerning the different isomeres of carotene. The accuracy of these measurements is, however, seriously affected by a number of experimental difficulties which must be overcome in order that entirely reliable data can be obtained.

In consideration of its fundamental importance for the determination of the molecular structure of carotene, a careful redetermination of the degree of unsaturation of the molecule was carried out. It has been found that every form of carotene thus far examined absorbs 11 moles of hydrogen per mole of pigment. This is in agreement with the results obtained by Zechmeister, Chohnoky and Vrabely and establishes this essential fact. Previous determinations of the oxygen equivalent of the two isomeres of carotene in which a small excess of potassium permanganate was employed gave a value of 43. Redeterminations of this value with greater excess of the oxidizing agent yielded values of 49 to 51, but no significant differences between the two forms of carotene were obtained.

Further attempts have been made by Dr. Strain to determine the structure of the carotene molecule through degradation experiments by the use of ozonization methods. Increased experience with these methods has shown that the yield of any given product varies within wide limits with slight changes in the conditions under which the ozonide is formed and decomposed. Also, slight changes in the spatial relationships and of groups within the molecule have been found to affect the yields of the products of ozonization. It is to be concluded, therefore, that calculations based upon a comparison of the quantities of any particular product resulting from ozonization may be quite misleading as to the structure of the molecule under investigation. By studying the products of ozonization of a number of compounds related to carotene it has, nevertheless, been possible to obtain further evidence concerning the structure of the carotene molecule. All forms of carotene thus far examined by this method yielded geronic acid in such quantities as would indicate that the carotene molecule contains at least one group from which this acid can be derived as a degradation product. This is also true of carotene to which two molecules of hydrogen have been added. These facts establish the relative position of 9 of the 40 carbon atoms in the carotene molecule. A number of other degradation products, *e.g.* carbonic, formic and acetic acids, have been isolated and quantitatively determined. Although the ratios in which these compounds are formed from carotene are

of significance in establishing the structure of the molecule, considerable supplementary evidence must still be secured in order to draw definite conclusions.

Mr. Milner has developed a method of isolating relatively large amounts of carotene from the mother liquors obtained in the extraction process of carrot roots. Because of the large amounts of fats in these liquors it has been impossible to recover all of the carotene contained in them. This process, which is based upon thorough saponification, has given increased yields of optically active carotene and also other products of interest.

Dr. C. B. van Niel of the Hopkins Marine Station again spent three months in our laboratory engaged on a cooperative investigation of the pigments of the purple sulphur bacteria. From the pure cultures of these organisms a total yield of 280 grams of air dry purple bacteria were obtained. From this, 81 milligrams of the beautiful purple crystalline pigment were isolated. This pigment is extremely easily affected by oxygen, although, in the absence of air, the purple crystals remained unchanged for at least three weeks. In general, the analyses and the determinations of physical properties of this material agreed very well with the results obtained last year by Dr. Smith and Mr. Milner. Elementary analysis by combustion show that the pigment has the empirical formula $(C_{16}H_{22}O)_x$ and that the formula probably is $C_{48}H_{66}O_3$. It melts at 218–219°. It has a characteristic absorption spectrum, with maxima of absorption in 95 per cent ethanol at 5280 Å. and 4950 Å. The molecule is highly unsaturated, absorbing 15 moles of hydrogen per mole of pigment, and the indications are that it has essentially an open chain structure and is closely related to the carotenoids.

One of the most interesting features of the purple bacteria is that they are capable of photosynthesis, although oxygen is not liberated in the process. These organisms also contain a green pigment, in general appearance bearing a striking resemblance to chlorophyll. Preliminary investigations indicate that the green pigment of the purple bacteria is, however, not chlorophyll and that special methods must be developed for its extraction in pure form from the bacteria.

A number of research workers in other institutions have been supplied with carotinoids of our preparation. Large crystals of carotene have been prepared for Dr. Gordon Mackinney for X-ray crystal structure examination. With this material, rotation and von Laue spot photographs have been obtained, and it is hoped that these investigations will aid in the elucidation of the structure of the molecule. Dr. Agnes Morgan of the University of California has been supplied with preparations of xanthophyll for use in nutrition experiments, and Professor J. C. Drummond of the University of London was supplied with small amounts of pure α -carotene for use in researches on vitamine chemistry.

CARBOHYDRATE CHEMISTRY

In previous reports (Year Book No. 23, 134; No. 24, 151) mention has been made of investigations on the oxidation of carbohydrates and related substances by means of a biocatalytic oxidation model. In this relatively simple system the oxygen carrier is a complex compound of iron, sodium

ferroporphosphate; the oxidations are carried out with atmospheric oxygen, at ordinary temperatures and in a medium having the same hydrogen ion concentrations as exist in the living cell. The model makes possible a study *in vitro* of the types of oxidations which occur in the living cell. In order to gain a clearer conception of the course of carbohydrate catabolism, it is important to determine the intermediate products which are formed in this complex process. These intermediate products are, however, extremely difficult to isolate or even to detect. Some idea of the course of carbohydrate oxidation may be gained from a study of the behavior of such compounds which, either from observation or from purely theoretical reasons, may be regarded as intermediate products in carbohydrate catabolism and which can be obtained through chemical synthesis. The first step in carbohydrate catabolism is in all probability a splitting of the hexose molecule into two triose molecules, *i.e.* into glyceraldehyde or dihydroxyacetone. These molecules are susceptible of change in a variety of ways, resulting in totally different end products, according to the course of catabolism which is followed. There is thus a competition between these molecules as to whether they will undergo alcoholic fermentation, total oxidation or utilization in syntheses and their fate depends largely upon catalytic factors and the oxidation-reduction potential of the system.

It has been found that in the catalytic oxidation model both glyceraldehyde and dihydroxyacetone are oxidized to carbon dioxide with surprising ease. On the other hand, methylglyoxal, which is a dismutation product of these substances and which has been isolated as an intermediate product in alcoholic fermentation, has been found to oxidize only very slowly. In the model oxidation apparently pyruvic acid is formed, another intermediate product of alcoholic fermentation found in the living cell. This purely chemical evidence throws some light on the conditions which determine the orientation of the different possible reactions of the sugar molecule. A variety of other compounds, chemically related to those already mentioned, have been studied as to their susceptibility to oxidation. Propylene glycol, trimethylene glycol, *n*-propyl alcohol, iso-propyl alcohol, propyl aldehyde are not oxidized at all, while glycerol, acetol and cyclic compounds with more than two hydroxyl groups are oxidized with ease.

It has been suggested that in the biocatalytic oxidation model the formation of carbon dioxide may be due to the presence of micro-organisms rather than to the purely catalytic action of the iron complex. This objection has been met in three different ways. First, through the cooperation of Dr. C. B. van Niel the number of viable bacteria was determined in the liquids immediately after making up the solutions, as well as at the time when the evolution of carbon dioxide had become maximal. These bacterial counts show clearly that living microorganisms can not have played any measurable part in the oxidation of the organic matter. Secondly, the solutions were sterilized and the air stream which was used as a source of oxygen was filtered through cotton plugs. Under these conditions the rate of oxidation was unchanged. Finally, the oxidations were carried out with the addition to the solutions of 0.2 grams of mercuric cyanide. This also produced no change in the rate or total amount of oxidation.

In 1914, J. U. Nef (Ann. der Chemie, vol. 403, 204) reported that he had succeeded in synthesizing complex polysaccharides from simple sugars by the use of a variety of reagents such as sodium carbonate, calcium acetate and lead acetate. This discovery, which is of great significance from the biological as well as the theoretical chemical viewpoint, has been recorded in the literature of the subject. Nef's experiments have been repeated a number of times by us during the course of several years, both by following explicitly the original directions and by modifying these in a number of ways. Under none of these conditions, however, was it possible to detect any polysaccharide synthesis from the simple sugars used.

The rare sugar alcohol, d-sorbitol, has been found by Dr. Strain to occur in Toyon berries, the fruit of *Photinia arbutifolia* Lindl. Methods of extraction and purification have been worked out, so that this plant material now offers a convenient source of this rare and costly compound. It has been obtained in relatively good yields, 6.1 kilograms of fresh berries giving 117 grams of the pure substance. Previous to this discovery the best source was the European box elder. The Toyon thus provides a local source which is of wide distribution on the Pacific coast. The compound which previously was very expensive has now been prepared in sufficient quantity to permit a more thorough study of its properties and of methods for its identification and separation from mixtures of related compounds. The rôle of compounds of this nature in plant and animal metabolism is as yet imperfectly understood, and experimentation in this field to a large measure depends upon a satisfactory supply of the material.

THE POLYURONIDES

The group of plant compounds known as the pectin bodies, or polyuronides, is characterized by the presence of at least one uronic acid molecule in the complex. The importance of the group becomes apparent when one realizes that it includes various modifications of pectin, the plant gums, plant mucilages, certain of the hemicelluloses, as well as some of the polysaccharides synthesized by bacteria. Research within the last decade has shown that the group of compounds is far more widely distributed and of much greater importance, both from a practical and from a theoretical point of view, than was formerly realized. In many cases, notably among the seed coats of some plants and in the wood of most trees, polyuronides make up a large part of the material. The origin of these substances and their relation to each other, as well as their composition and structure, is but little understood at the present time.

For some years Dr. Anderson and his associates at the University of Arizona have been studying the composition of certain groups of the polyuronides, notably the plant gums, plant mucilages and the hemicelluloses. His aim has been to determine not only the composition of these bodies but also their origin in the tree. Although these substances are chemically closely related, their interconversions involve more intricate reactions than has been commonly assumed. Thus, for example, it has been found that the composition of the gum of lemon wood is very different from the hemicellulose of this wood and the gum can not be considered as arising from the hemicellulose.

It has become evident that further progress in this field demands more exact information of the location within the plant of the various polyuronides which are extracted by chemical means and the extent to which these substances are removed from the wood or altered by any specific treatment. This information can to a considerable extent be supplied by microscopical examination of the wood preparations and carefully following the changes which are brought about in these preparations in the various steps of extraction and chemical treatment. The researches of Dr. Anderson and Dr. Bailey have thus proved to be mutually helpful by bringing to bear two very different methods to the same general problem.

During the summer of 1932, Dr. Anderson was able to complete the analysis of the polyuronide of flaxseed. One of the most interesting features of this work has been the discovery of the levo form of galactose as a component of this substance. At the same time a study was begun of the mucilage that occurs in the bark of slippery elm, and this has since been completed. With the development of useful methods it has now been possible to develop a program involving closer cooperation of the efforts of Dr. Anderson and Dr. Bailey in the study of the composition of the various polyuronides of wood and their relation to each other. For this purpose the wood of the black locust has been chosen. The trunk of this tree has been divided into three portions, namely, the inner bark, the sapwood and the heartwood, and a careful investigation has been begun on the polyuronides of each of these divisions.

INVESTIGATIONS ON CAMBIUM AND ITS DERIVATIVE TISSUES

By I. W. BAILEY

CYTOLOGICAL AND HISTOLOGICAL ASPECTS

Techniques for studying the cambium and its derivatives, both in living tissue and in sections treated with chemical reagents, have been considerably improved during the last year. Significant data have been secured through the study of extremely thin sections in polarized light. Dr. Thomas Kerr, National Research Council Fellow, has perfected methods for the micro-injection of the living cells of the cambium and has assisted in the study of "A-type" and "B-type" vacuoles, particularly of certain aberrant types of transitional or intermediate character.

PHYSIOLOGICAL AND BIOCHEMICAL ASPECTS

Emphasis has been focused upon the study of the structure and development of cell membranes, upon changes that occur in the cambium during transitions from the resting to the growing conditions and upon such as occur during tissue differentiation, *e.g.* liquefaction. It is evident that future progress in dealing with these complex phenomena is dependent upon close cooperation between experts in various scientific disciplines. At present, the biologist is handicapped through the lack of reliable microchemical methods and the chemist and physicist are unable to visualize the number and magnitude of the biological variables. In the case of the derivatives of the cambium, the complex mixtures of celluloses, hemicelluloses, pectic compounds, "lignin," phenolic compounds, etc., have been found to vary markedly not only in different species and in plants grown under different environmental condi-

tions, but also in different parts of the same tree, in different cells of the same tissue and in different layers of the cell wall. Standardized and stereotyped chemical techniques for the extraction and purification of cellulose, hemicellulose, "lignin," pectic compounds, etc., which are applicable in the study of cotton, seeds, fruits, etc., should be modified more or less extensively in the investigation of the derivatives of the cambium.

In cooperation with Professor Anderson and Dr. Kerr, methods are being developed for locating and studying the polyuronides and other complex polysaccharides *in situ*, and for improving techniques in the isolation and purification of such compounds.

PALEOBOTANICAL ASPECTS

During the last two years, and through the cooperation of Professor Douglass, Dr. MacDougal and Dr. Haasis, materials have been assembled for an intensive study of the range of structural variability in the redwood, *Sequoia sempervirens*. Anatomical characters, used in keys for identifying the woods of Coniferæ, vary within relatively wide limits in the redwood. Indeed, the range of variability is so great that isolated fragments from a single tree might be classified in different genera or even sub-families. This strengthens our previous contention that future progress in those fields of paleobotany which are concerned with fossil woods is dependent largely upon a more intensive study of living gymnosperms and angiosperms, *i.e.* of authentic specimens not only from different genera, species and geographical races, but also from different parts of the tree and from trees grown under different environmental conditions.

GROWTH IN TREES

RELATION OF LEAF SURFACE TO AMOUNT OF WOOD FORMATION, BY D. T. MACDOUGAL

If the total area of the surfaces of the leaves of a tree is estimated and the volume of the wood laid down in any season computed, some measure of the photosynthetic activity of the green surfaces may be obtained. The figures obtained will have their greatest value in trees in which the products flow directly to the region of the cambial tissues with a minimum of surplus accumulations.

The Monterey pine presents such conditions. Leaf-areas were determined by calculations based on weight of leaves of various ages, the oldest of which bore over 3 million leaves. Estimates based on such data were made of older trees, one of which was taken to carry 10 million leaves, with a total area of 1090 square meters (about one-fourth of an acre).

The wood laid down annually by Monterey pine No. 19, a young tree, was equivalent to a layer 0.20 to 0.38 mm. in thickness on the total green surface in 1925. Layers from 0.27 to 1.30 mm. were formed by No. 20, 1923-1932. This tree was 16 to 18 years old at the end of the period.

No. 1, which was 28 years old in 1918, manufactured wood equivalent to a layer 0.12 to 0.49 mm. in thickness 1919 to 1932. No. 28 was 70 years old in 1921 and formed material to make a layer 0.05 to 0.20 mm. in the decade following.

The lesser net products of aging trees may be safely ascribed to use of energy (material) in lifting and transporting material for greater distances in trunks, branches and roots.

The maximum net production occurred in No. 17, a young tree, 1923 to 1929. The wood formed annually was equivalent to layers 0.96 to 1.50 mm. in thickness. The dominating factors in photosynthetic activity are temperature, soil-moisture and sunlight. This tree had at all times an adequate supply of water.

PENETRABILITY OF LIVING STEMS TO AIR, BY D. T. MACDOUGAL

Previously described experiments have established the fact that the gases of the pneumatic system are usually at a pressure not more widely different from that of the atmosphere than the equivalent of 10 to 20 mm. of mercury. This fact implies minute radial communications in the wood (visible) and across the cambium (not demonstrated microscopically) through which gases of the air may pass by streaming.

A special form of extraction apparatus has been designed to test the rate at which air may be drawn radially into small stems. Sections of stems are sealed to an outlet of a burette in which suction may be set up by a column of mercury. The free end of the section is similarly connected with a vertical tube of small bore, the end of which is stepped in a dish of mercury. This acts as a register of the suction extending lengthwise through the section.

Air drawn from the section into the burette includes that present in the section and also what may be drawn radially into it. Hitherto all extractions have been made with suction of 100 mm. of mercury exclusively. This air must pass through the bark, which appears to offer but little resistance to streaming gases, and through the cambium made up of the initials and a few layers of derivatives. The resistance of the wood may not readily be determined but may be assumed to be much less than that of the cambium, which is usually the limiting factor in radial flow. The stems used comprised no more than 5 or 6 seasonal layers of wood.

The flow of gas into willow stems was about 0.001 c.c. hourly per square centimeter. The flow in sections mounted in the laboratory and becoming dried out rose to 10 to 25 times this rate within a week. In older, denser stems the rate was 0.002 c.c. initially and rose to four or five times this rate.

In young stems of *Quercus agrifolia*, initial rates were from 0.03 to 0.08 hourly per square centimeter. *Q. hypoleuca* showed a rate of 0.02 to 0.04 c.c. Initial rates as low as 0.003 c.c. hourly per square centimeter were found in leafy internodes of the Monterey pine. Higher rates of 0.016 and 0.02 c.c. were found in internodes which had cast their leaves. Increasing rates with continuation of the extraction in the dry air of the laboratory generally followed. This was taken to be due to the deterioration of the cambium.

The porosity of living stems thus demonstrated is such that barometric variations and temperature changes, as well as the pressure of gases freed by living cells, would cause outflow and inflow of gases.

CONTINUOUS AND DISCONTINUOUS GROWTH OF CAMBIUM, BY D. T. MACDOUGAL

The capacity of the cambium layer of trees to carry on growth without cessation or rest and without rhythm, as exemplified by the Monterey pine, has been previously described. A similar condition exists in the Monterey cypress. A dendrograph attached to a tree 12 cm. in diameter late in 1931 revealed the fact that the trunk was in a state of active enlargement at that time. The record shows continuous growth activity through the 20 months since the observations were begun.

The behavior of the green smooth stems of the desert palo verde (*Parkinsonia microphylla*) is in striking contrast. An instrument attached to the trunk of such a tree in 1920 showed no enlargement. The instrument was taken to be faulty and the observations discontinued, to be resumed in February 1929 with an improved apparatus. The record now extending into the fifth season shows that there was a net decrease in the diameter of the trunk in the seasons of 1929, 1930 and 1931. In the fourth year a net increase of 0.44 mm. was measured. The trunk, which is sound, healthy, with a green smooth bark, has at this date (July 1933) a diameter 4 mm. less than at the beginning of 1929. These observations indicate that areas of cambium may remain inactive for long periods despite the fact that the majority of the thin branches elongate and bear leaves every season.

To what extent the activity of the cambium extends downward from such active growing points can not be conjectured. Marked concentric zonation of the wood occurs. X-ray images of cross-sections show that this is not due to annually formed or seasonal layers of wood. Inhibition of the activity of the cambium as a traumatic effect of pruning, topping or defoliation is well known in many trees. It seems to be a normal procedure in *Parkinsonia*. The implied inactivity may be due to growth-inhibiting substances which may also be responsible for the long life in a dormant condition of cells in *Parkinsonia* trunks. Some of the living elements have an estimated age of between three and four hundred years. Many incompletely differentiated wood fibers, tracheids and other elements are found several inches inward from the surface of the trunk.

WINTER AND SPRING SHRINKAGE OF DECIDUOUS AND EVERGREEN TREES,
BY FERDINAND W. HAASIS

Previous reports on seasonal shrinkage in trees, in Year Books 30 and 31 and elsewhere,¹ have had to do mainly with diametral decreases occurring in dry weather in summer or fall. As has been mentioned, however (Year Book No. 31), the deciduous big-leaf maple experienced shrinkage while in a leafless condition and while the leaves were unfolding. For bald cypress, slight shrinkages in diameter have been observed at the Coastal Laboratory during the period of leaf opening.

The dendrographic records for Arizona walnut, *Juglans major*, growing at the Coastal Laboratory, indicate that in this species, shrinkage is very likely to occur during the leafless period, although the trees studied are growing on a moist site, and in spite of the fact that the leafless period corresponds fairly closely with the rainy season. A white ash, *Fraxinus americana*, to which a dendrograph was attached at the Coastal Laboratory in March 1933, showed a few weeks of shrinkage in March and April. In the evergreen redwood and California laurel, also, a considerable amount of shrinkage is apt to occur during the cool season, in spite of soil moisture evidently sufficient for growth.

At times the two types of shrinkage become confluent in both deciduous and evergreen trees; and it may even happen that many months elapse before the decrease is canceled and net growth begins. One walnut tree began to shrink in August 1928 with the leaves still largely in place. Shrinkage continued into the winter and spring. While intervals of increase interrupted the latter shrinkage, sustained enlargement did not begin until the leaves were well developed in May 1929. It was not until well into July that the

¹ Ferdinand W. Haasis, *Seasonal shrinkage of Monterey pine and redwood trees*, Plant Physiology, vol. 7, 285-295, 1932.

tree had regained its diameter of the preceding August. In August 1929 the æstivo-autumnal shrinkage began again. This merged into the hiemal-vernal type, interrupted by some weeks in which enlargement occurred. Sustained increase began the end of March 1930, but it was not until the end of May (when some of the leaves were full grown) that the shrinkage was canceled.

The course of diametral changes for this tree during the 21-month period is indicated below:

Date..	Aug. 13	Nov. 26, 1928;	Feb. 25	May 27,	Aug. 26, 1929;	Nov. 25	Feb. 24	May 26, 1930
Relative diameter,								
mm. ..	0.0	- 1.0	- .15	- 1.5	- 0.2	- 0.4	- 1.0	+ 0.3

While the records are poor for a few weeks during this time, these would not greatly affect the above figures. It is true that better records would probably have shown for 2 or 3 weeks in July and August 1929 relative diameters slightly above that of August 13, 1928. Aside from this, the uncertainty of the figures is insignificant.

The causes of the winter shrinkages are not clear. The spring shrinkages may be traceable to removal of stored food products from the stem. It is evident that in making studies of the time at which growth begins in the spring, cognizance must be taken of any shrinkage which has occurred since diametral increase last stopped. When shrinkage has occurred, then part of the vernal increases are probably due to rehydration rather than growth. When studies of diametral increase are begun in the spring, without knowledge of previous shrinkages, conclusions as to both time and amount of growth may be somewhat in error.

GROWTH OF A REDWOOD (*Sequoia sempervirens*) SUBSEQUENT TO DECAPITATION, BY FERDINAND W. HAASIS

In July 1924, the top was sawed off a redwood tree (No. 9) about 1 dm. in diameter, leaving a stump 2 meters in height. A brief description of the subsequent branch growth and bole shrinkage of this tree has been presented in Year Book No. 31. A more detailed examination of the tree was made in the fall of 1932 which permits of further analysis of the tree's physiological activities after the loss of the top.

Decapitation had removed a straight central stem 53 dm. long. Eight years later the stump bore at or near the top two long branches, 26 dm. and 19 dm. in length, respectively, variously branched, somewhat crooked and only approximately erect. In addition, there were a number of smaller branches of various ages originating here and there on the stump.

The cambial activity of this tree had obviously been of an extremely spotty nature. At the 4-cm. base of the 19-dm. branch, for example, the annual growth layers for the years 1925 to 1932 were easily distinguishable. In contact with the 1924 layer, these 8 layers ran together on both sides of the branch to a total thickness of 1 or 2 mm. at a distance of 4 cm. from the branch pith. On the opposite side of the bole these layers appeared to be entirely absent for a circumferential distance of 1 cm. Below the branches, similar tapering off was observed. The branch base just mentioned (with 8 layers totaling 2 cm. in thickness) was represented half a decimeter down by 6 layers with a total thickness of 5 mm. Over a considerable portion of the bole, the growth external to the 1924 layer was absent or indistinguishable. The total thickness for the 8 years would not amount to more than 0.1 mm., if present at all.

It seems quite evident that the food manufactured in the developing branches went first to building up the branches themselves, that the branch bases were gradually extended around, down, and up the bole year by year, and that material would have been available for general appreciable increase in bole thickness only when the branches had become large enough to produce food in considerably greater amounts. Apparently, as a dormant bud opens and develops into a branch, not only does increase in length and thickness of the branch take place, but at the same time there are added to the bole over a restricted area tapering layers of new growth spreading out in all directions from the branch base and thinnest at the periphery. In time the layers from several branches presumably become confluent and general bole accretions ensue. A mechanical injury caused by the removal of a chip in 1931 was followed the next year by the development of scar tissue radiating out like the branch-base growth for a distance of 3 cm. on each side. This traumatic tissue had a maximum thickness of 4 mm. and was apparently in contact with the 1924 layer.

Although the decapitation was probably the severest experience in the life of this tree, the suppression of growth layers has been by no means uncommon in its history. At various heights one ring or another has been pinched out for a space of a few degrees of circumference, sometimes on one side of the tree, sometimes on another. At 1 dm. above the ground, the main outer ring (that of 1924) was the twentieth outside the pith, on one radius, but as low as the sixteenth on another. Even the big 26-dm. branch formed after decapitation lacked the 1931 layer for a distance of 45°, a decimeter above the cut top

EXPERIMENTAL TAXONOMY

BY JENS CLAUSEN, DAVID D. KECK AND WILLIAM M. HEUSI

The problems, objectives, methods and materials for these investigations were stated in Year Book No. 31, pages 201-205. In accordance with this program, a reorganization of the materials has been undertaken during the past year to enable the group to concentrate upon the most promising problems and to increase its efficiency.

MADINÆ

The main emphasis has continued on the investigations of this subtribe of helianthoid Compositæ. Over 300 cultures representing some 55 species of these plants have been raised to maturity this year and studied both under greenhouse and garden conditions. From the taxonomic viewpoint, these cultures have yielded valuable data on the composition of genera, species, races and biotypes, and the stability or variability of the multitudinous forms. They have made it possible to reach conclusions regarding the true value of taxonomic characters and have shown the correlation between small morphological differences and geographic distribution. This living material has also made possible more accurate descriptions and illustrations than would have been the case in using herbarium material alone. The mere assemblage of numbers of forms within the species has made obvious important similarities and differences hitherto overlooked in spite of the rather exhaustive field and herbarium studies.

Field studies have added much critical material and data to the Madinæ investigations. Preparation of manuscript for the taxonomic account of this group is receiving first attention and Mr. Link Malmquist has completed an excellent set of ink wash drawings to illustrate the monographic work.

Seeds have been collected this season which, when grown in 1934, will bring almost all the known taxonomic units into cultivation. The chromosome number has been ascertained for practically all cultures of the past three seasons and the degree of self-fertility of the various species has been determined. About seventy species and forms have been selected for attempts on intercrossing. Many of these have been used repeatedly for intraspecific, interspecific and even intergeneric crossings in order to build up a body of valuable genetic data on the *Madinæ*. The crossings have been made largely in cages in the greenhouse and to some extent in the field. Several F_1 populations have been grown in 1933; some of these are completely sterile and seed from others will yield much larger F_2 populations in 1934.

This year the possibilities of natural hybridization as an agency in obtaining seed from interspecific crossings was tested. In isolated positions, one plant of a self-sterile species was grown in the field surrounded by a ring of individuals of a related species whose ability for natural crossing with the former was to be tested. Twenty-five different combinations were tried in this way.

While most species of *Madinæ* are cytologically constant, a few, notably *Hemizonia fasciculata*, *H. virgata-heermanni* and *H. pungens*, which have a number of geographically differentiated races, have varying chromosome numbers. A close correlation exists between certain morphologic characters and the chromosome number. For instance, in *Hemizonia pungens* the types without pappus, of which there are several, have $n = 9$, while those with pappus have $n = 12$. A Sacramento Valley late type has been found to vary between $n = 10$ and 12 , but some of these individuals may be derivatives of natural hybrids. Mr. Palmer Stockwell has assisted Dr. Clausen in the cytological investigation.

Dr. D. A. Johansen has brought to the stage of publication his cytological investigations on *Madinæ* cultivated in 1931 and 1932.

Of the twenty interspecific crossings attempted in 1932, offspring has been successfully grown from the following:

Layia elegans \times *L. platyglossa* and reciprocal

Layia platyglossa \times *L. jonesii*

Hemizonia virgata, $n = 4$ \times *H. heermanni*, $n = 6$ and reciprocal

H. virgata, $n = 6$ \times *H. heermanni*, $n = 6$

Intraspecific crossings successfully completed, of equal interest with the above, include *Hemizonia pungens congdoni*, $n = 12$ \times *H. pungens typica*, $n = 9$ and the reciprocal, and *Layia platyglossa*, prostrate maritime ecotype \times erect inland ecotype.

ZAUSCHNERIA

Progress of the investigations on this genus has been largely along two lines: (a) crossing in all directions *inter se* of selected types, (b) field studies leading to new collections.

The eight individuals selected for intercrossing belonged to the following groups: (1) Southern narrow-leaved diploid from two climatically differing stations; (2) northern broad-leaved diploid; (3) coastal narrow-leaved tetraploid; (4) moderate altitude intermediate tetraploid from two stations; and (5) high altitude broad-leaved tetraploid from two stations.

The results of these crossings showed: (a) all diploids intercrossed and gave good, viable seed irrespective of geographical remoteness and morphological dissimilarity of parent types; (b) all tetraploids intercrossed and yielded viable seed; (c) tetraploids and diploids crossed only with difficulty, irrespec-

tive of geographical proximity of their origin and their morphological resemblance, the resulting seed was poor and very little of it germinated; (d) self-pollinations were successful in all types.

The offspring from self-pollinations of the eight selected types segregated various lethal and semi-lethal types, mainly because of chlorophyll deficiency. These were 3:1 ratios in the diploids and tetrasomic ratios in the tetraploids. Subsequently it was found that the chromosomes of a tetraploid form conjugated in groups of four, while those of a diploid form conjugated in normal pairs.

In 1931 only one individual of the northern diploid form was in our cultures and its distribution was very imperfectly known. This form was the subject of field studies in the fall of 1932, at which time its range was traced along the basins of the Trinity, Mattole and Eel Rivers, where it extended north and south for some 100 miles. It occurred alone through most of this range, but the tetraploid *latifolia* type protruded upon it from the east and south and was there associated with it.

Our first Arizona type to be cultivated came from south of Tucson. Its appearance is suggestive of the Sierran *latifolia* and it has been found to be tetraploid.

POTENTILLA, PENSTEMON AND VIOLA

Additional information gathered on these three genera has been largely of a cyto-genetic nature. New chromosome counts were made in *Penstemon* and it was discovered that the morphologically complex groups of *Penstemon confertus* and *P. newberryi-davidsonii* each consist of diploid and tetraploid forms.

The extremely different alpine and foothill types of *Potentilla glandulosa* were crossed and F_1 plants obtained in both directions. It is planned to have equal samples of the F_2 populations planted at Stanford, Mather and Timberline transplant stations in order to study natural selection acting on a hybrid swarm under very different climates, and to observe whether nature re-selects the same morphological and physiological type native to each environment.

Some studies on ecotype differences among European *Nomimum* violets and on synthesis of *Melanium* species have marked this year's *Viola* studies. Material of the Californian violets has been assembled in cooperation with Mr. Milo S. Baker, of the Santa Rosa Junior College, and new chromosome counts made. The group including *Viola purpurea*, *nuttallii* and *præmorsa* constitutes a cytologically as well as taxonomically very complex problem.

TRANSPLANT EXPERIMENTS

Mr. Heusi has made a critical review of the accumulated data gathered from the beginning of these investigations and has coordinated them. This review has disclosed many gaps in our knowledge that must be filled by further experiment, but, above all, it has given valuable information as to what to expect from transplant experiments, their scope and general value and how to conduct them most successfully.

On the basis of all this information it was decided to reorganize the investigation and to concentrate on certain aspects of it. A new series of experiments has been started simultaneously at the three stations, namely Stanford University at about 30 meters, Mather in the Yosemite region at 1500 meters, and Timberline near the crest of the Sierra Nevada in the Harvey Monroe Hall Natural Area at 3300 meters elevation. At Stanford the plants are set out

in a level, open field. At Mather and Timberline there are comparable open gardens in the center of a mountain meadow. At Mather, in addition, there are created four locally different gardens for a water-light variation series of transplants, including (a) dry sun, (b) dry shade, (c) wet sun, and (d) wet shade. At Timberline many plants are also grown on a south-facing slope.

Eventual changes in taxonomic characters will be followed as previously, although evidences in this direction hitherto have been mainly negative. But in addition to this phase of the study special emphasis will be laid upon the evolutionary aspects of plant height and vigor at different climates, time of flowering, ability to fruit, survival differences, and duration and character of dormancy. The three stations with their extreme differences in climate offer a unique opportunity for such studies.

Several considerations have determined which species and genera should be included in the transplant experiments: (1) To utilize wherever possible representative stock of material, already in the transplant gardens and made very valuable by careful notes and observations through a series of years; (2) to lay special emphasis upon species and genera occurring naturally at the various elevations all the way along the transect of the three transplant stations; (3) to include materials of evolutionary significance and species with many as well as those with few ecotypes; (4) to utilize almost all types of herbaceous perennials in the phanerogamic system in order to ascertain whether results obtained are of a general nature; and (5) to include many individuals of some species and also series of individuals from single localities as a check against results due to chance selection. *Potentilla* and *Zauschneria* appear to be the most promising genera introduced into these experiments, so they continue to be the most extensively used. A few transatlantic transplants are being included, when the species have a transatlantic distribution. Where adequate, the transplant experiments are supplemented by taxonomic and cyto-genetic investigations.

The transplant experiments fall into the following three categories: (1) Standard environment transplants, mainly grown at Stanford, in which forms from very numerous environments are grown side by side under similar conditions; Madinæ, being annuals, are subjected to only this form of transplant experiment; (2) climatic variation series (interstation transplants), in which portions of each individual are grown simultaneously at the three climatically different stations, and (3) water-light variation series, in which portions of each individual are grown simultaneously under the four locally different conditions at Mather, mentioned above, in addition to being included among the climatic variation series, and most of them are also grown on the Timberline slope; each individual of this third category will thus be exposed to seven or eight different environments.

About 430 collections are at present assigned to the climatic variation series and 110 to the water-light variation series. This might seem a small number had not the individuals been chosen with much discrimination as to their contributory value in these experiments. Also, it has been decided that this number of individuals can be carefully followed by the present staff through every step of their development.

A soil sterilizer has been added to the equipment at the central laboratory. This consists of a large outdoor oven of brick construction, with stucco exterior, in which moist potting soil is heated until all seeds in it have been killed. It is essential in raising critical seedling cultures that there should be no foreign seeds in the potting soil. This sterilizer has been so satisfac-

tory that all soil used in the greenhouse is now treated thus. In addition to eliminating the problem of weeds in the greenhouse, the sterilization has been found to improve the quality of the soil.

DESERT INVESTIGATIONS

UNDER THE DIRECTION OF FORREST SHREVE

The desert region of North America is separated by the continental divide into two areas which are isolated from each other by forested mountains or by grassy plains which are arid but of such an altitude as to have cold winters. The South American desert likewise has two areas, which are still more effectually separated by the loftiest part of the Andes. The western section of the North American Desert extends from southern Sonora to eastern Washington, the eastern section from Oaxaca to central New Mexico. Many features of the vegetation are similar in the two sections and many problems are common to both of them. At the same time there is evidence that the history of their plant life has been independent in important respects. The northern and southern parts of the western section also exhibit differences in vegetation, but the only barriers by which they have been separated are climatic ones and their history has been closely connected. The northern part comprises the Great Basin and the Mohave Desert, the southern includes the Colorado Desert in California and the desert parts of Arizona, Sonora and Baja California. The latter region as a whole is best known as the Sonoran Desert, since the largest part lies in the Mexican state of Sonora. It embraces an area of about 118,000 square miles surrounding the head of the Gulf of California and stretches from 27° N. lat. to 35° N. lat. The eastern edge of the Sonoran Desert lies between 2000 and 3500 feet in elevation and has a rainfall varying from 8 to 12 inches per annum. The remainder of the area is chiefly below 2000 feet and has extremely low rainfall. The Sonoran Desert exhibits a strong biological unity, has been the path for the northward migration of many subtropical groups of plants and animals, and has been the seat of development of many striking structural and functional features by which its plant life has reached adjustment to the extreme conditions. The northward movement of plants in this region has encountered decreasing precipitation and increasing severity of winter temperature conditions. The outcome of the adjustment of plants to the conditions met here has been the appearance of several families and genera and a large number of species of plants that are endemic to the region.

The Desert Laboratory is located near the eastern edge of the Sonoran Desert and about midway between its northern and southern ends. The work carried on at the Desert Laboratory since its establishment has been principally concerned with the plants and physical features of this part of the North American desert. An adequate knowledge of the behavior of desert plants requires both extensive and intensive work. Sound conclusions must be based on knowledge of a given plant throughout its range. These considerations have led to gradual extension of the work of the Laboratory over a larger area in both its observational and experimental phases.

A program is now being developed, the aim of which is to carry out a comprehensive investigation of the plant life of the entire Sonoran Desert. The basic feature will be a thorough study of the flora, which is imperfectly known and is covered only in small part by existing regional publications. The results of this work will throw light on the origin and relationships of the flora. An equally important feature will be the determination of the geo-

graphical ranges of certain dominant plants and the study of their habitat requirements in different parts of the area. The plant communities will be investigated with regard to their floristic composition, their geographical variation and their relation to soil and climate. Study of physical conditions will be undertaken in certain selected localities. Attention will be given to some of the outstanding types of structure and physiological behavior which have appeared in the plants of the area. The prosecution of such a program will increase knowledge of an important American desert area and will organize much of the unpublished or scattered information in regard to it. It should yield important results on the ecological relations of desert plants and on the processes involved in the migrations and evolutionary development of plants entering a very arid region and persisting in it.

A cooperative arrangement has been made with the Dudley Herbarium of Stanford University, by which joint field work will be carried on throughout the Sonoran Desert, contributing at the same time to a knowledge of the flora and of the character and distribution of the vegetation. Other joint arrangements are being perfected which will bring as much palæontological and physiographic evidence as possible into the consideration of the biological development of the area. Arrangements have been made for the study of the developmental morphology of certain plants by investigators already interested in closely related forms. It seems particularly important to secure as much evidence as possible on the relationships of such families as the Cactaceæ and Loasaceæ, both of which have reached their principal development in the American deserts, and such families as the Fouquieriaceæ, which appear to have originated in the Sonoran Desert. It is hoped that by cooperative effort similar work can be extended to other groups which have made great evolutionary strides in the Sonoran area.

During the last six months, considerable time has been devoted to organizing existing information about the Sonoran Desert. Maps have been assembled and as much information as exists has been brought together in an effort to delimit the outlines of the area as accurately as possible on a purely vegetational basis. Titles to literature on the physical and botanical features of the area have been collected and Mr. Turnage has made a gazetteer of localities cited in descriptive literature or mentioned in connection with plant collections. A provisional card list of plants has been prepared, based on published records and on the files of the Desert Laboratory. This includes the species of importance in the make-up of the vegetation, and will be used in connection with ecological work. A similar card file is being developed by Dr. Wiggins at the Dudley Herbarium, as a basis for the complete taxonomic treatment of the area. A file of outline maps has also been begun for recording localities for all plants showing distributional features of interest, as well as for records of distribution of leading plant communities. Climatological data for the Sonoran Desert are also being assembled. Temperature and rainfall records for 35 stations in Sonora and Baja California have been courteously furnished by Sr. J. C. Gomez, Director of the Mexican Meteorological Service. The two lines of instruments that have been maintained across the Sonoran Desert for several years have been continued and extended by Dr. Mallery, and additional instruments have been placed in the region between Magdalena and Guaymas.

DESERT EXPLORATION

Three expeditions were made during the past year, on which routine observations were taken along established routes and new territory was examined

in Arizona and Sonora. In October 1932, Dr. Shreve and Dr. Mallery, accompanied by Dr. I. L. Wiggins and Mr. Turnage, visited the line of rain gages from Tucson to Port Libertad, Sonora, and returned across the coastal desert region in an easterly direction to the railroad a short distance south of Noria. Opportunity was thus given to study a section of Sonora lying about halfway between the better-known regions along the International Boundary and the valley of the Sonora River. The inner limit of the coastal type of desert was located for this latitude and the distributional boundaries of many of its characteristic plants. The vegetation of an extensive area of granitic soil lying between 1000 and 1500 feet in elevation was found to resemble that on similar soil at higher elevations far to the north. A mature playa lying about 60 miles south of Pitiquito was found to be dominated by a nearly pure open stand of *Prosopis*. Limestone hills about 35 miles south of Las Trincheras were seen to be covered with a heavy and diversified stand of shrubs and to be almost devoid of cacti. In the region east of La Cobriza is a grassy plain, poor in both shrubs and cacti, but fringed with trees along the drainageways and extending for over 50 miles. The entire transect from the Gulf to Noria showed a surprising variety of vegetational types, each of which stands in close dependence upon particular soil conditions.

In February and March 1933 an expedition was made to southern Sonora by Dr. Shreve, Dr. Mallery, Dr. Wiggins and Mr. Hinckley. The plains and hills which lie south of Hermosillo and east of the railway were examined, also the coastal region from San Carlos Bay southward to the delta of the Yaqui River and the coastal plain immediately south of the Yaqui. Low mountain ranges were traversed from Cajeme to Tesopaco and Cedros, as well as extensive plains between Quiriego and the Gulf. The principal objectives were to investigate the gradual change in the vegetation from northern to southern Sonora, to secure plant collections and to attempt to locate the line of transition from desert to thorn-forest. Additional work was accomplished on habitat conditions for *Larrea* (*Covillea*) and *Encelia*. The former was studied at and near its southern limit on the west coast of Mexico, and the latter at several of the localities in which it assumes the rôle in the vegetation that is played by *Larrea* farther north.

The line between desert and thorn-forest is neither sharp nor direct. Typical areas of the former are to be found south of the Yaqui River, while many features of the latter are developed as far north as Moreno. The southernmost deserts of the Sonoran coast are rich in plants that do not reach the United States nor the more arid region in northwestern Sonora. The northernmost thorn-forests are formed in the main by members of desert genera and are full of cacti of several types, but they also contain representatives of tropical genera. Like every biological frontier, this transition region is a fruitful field for studying the processes of plant distribution.

Immediately following the field work in southern Sonora an expedition was made westward from Tucson and northward through Yuma County, Arizona. The regular semiannual rainfall readings were made along the Camino del Diablo and the vegetation of the very arid plains and mountains immediately east of the Colorado River was examined at its most active season. The close sequence of the visits to the southern and northern parts of the Sonoran Desert did much to sharpen the observation of their contrasting vegetation as well as their physiographic and soil conditions.

In the late spring, Dr. Shreve and Dr. Mallery traversed the Mohave Desert from Barstow to Las Vegas, crossed the Colorado River just north of Boulder Dam, followed Detrital Valley to Kingman, and going east of the Hualapai

Mountains examined the valley of the Big Sandy and the broken country lying between there and Wickenburg. The aim of this traverse was to locate the northern limit of the Sonoran Desert in Arizona, to observe the features of transition from the Mohave Desert to the Sonoran, and to study the northernmost stands of *Larrea* in Mohave County, Arizona. Valuable data were secured for this region, which has had little botanical exploration. The *Larrea* plains of northwestern Arizona closely resemble those of the extreme southeastern corner of the state in their general physiognomy, but the plants associated with *Larrea* in the two regions are almost wholly different.

In connection with the exploration of the past year, Dr. Wiggins has collected nearly 1000 numbers of plants, many of them from localities never before visited by botanists. Irrespective of the new forms that are being found in this collection, it may be counted on to improve knowledge of the distribution of the flora of the Sonoran Desert and to aid greatly in the elucidation of its development.

ENVIRONMENTAL CONDITIONS

The two lines of rainfall stations extending across the Sonoran Desert from Tucson toward the west and southwest have been maintained during the past year by Dr. Mallery. Six new stations were established, making a total of 35 localities in which the Sykes' long-period rain gage is in use. In some places supplementary gages have been placed to safeguard the securing of data and to determine the variability of rainfall within short distances. The data that have been obtained since the establishment of the two series are not yet sufficient to give an adequate picture of the rainfall pattern for the Sonoran Desert nor to furnish reliable means in a region of such great variability of precipitation.

The routine records of rainfall, sunshine, air temperature and wind on the grounds of the Laboratory have been maintained and tabulated by Mr. Hinckley. The investigation of the moisture relations of the soil has been continued in the manner indicated in the Year Book for 1931-32 (pp. 207-208). The continuation of these records from year to year greatly enhances their value by permitting comparison of the effect which the highly variable seasonal rainfall exerts on the vast underground supplies of moisture on which all non-succulent perennial plants depend.

The spring of 1933 witnessed the longest period without effective rainfall in 26 years, extending for 25 weeks. The average moisture content of alluvial flood-plain soil has, however, fallen only 2 per cent below the average readings of two years ago, and the deeper levels of bajada soil have varied only slightly from their previous values. These facts are believed to be related to the prevalence of temperature during the drought period which were well below the average.

The amount of water present in the two surface meters of the soil is at all times such that the precipitation of one and a half to two years would be required to supply it. In 1931, 24 per cent of the rainfall was lost to the soil by runoff, and in 1932 only 4.7 per cent of it. The amount of evaporation from the soil varies greatly in direct proportion to its moisture content, being 12.4 L. per square meter per month in the arid fore-summer of 1931 and 82.1 L. per square meter per month for the same season in 1932.

PHYSIOLOGICAL BEHAVIOR OF DESERT PLANTS

Recent work has centered in the continued investigation of the physiology of *Larrea*, preliminary work on the water relations of four woody perennials

of the Sonoran Desert, and the germination behavior of certain trees and shrubs of importance in the vegetation in the latitude of Guaymas.

The unusually arid spring of 1933 provided an opportunity to make further determination of the osmotic value of the leaf sap of *Larrea* under conditions calculated to bring about the maximum values. Dr. Mallery has continued determinations of material from the areas on which he previously made an intensive investigation, the results of which are now in press.

Material of *Larrea* and *Encelia* was collected in March in many localities in southern Sonora, in connection with field investigations, for study of sap concentration, and samples were taken for determination of the properties of the soils in which the plants were living.

A study of the leaf history of *Larrea* has been begun for the purpose of learning more about its anomalous habit of intermittent leaf growth, the changes which the leaves undergo from the time of their formation until they are shed, and the length of life of individual leaves. It is expected that this work will throw more light on the drouth-surviving properties of *Larrea* and the extent to which they reside in the behavior of the foliage.

Several trees found in central Sonora have features of habit, stem structure and leaf character which are sufficiently unlike those of other desert trees to suggest that they may have unusual water relations. A preliminary investigation of the moisture content of the wood has been made in four of these trees: *Forchammeria watsoni* (Capparidaceæ), which has a very heavy perennial crown of deep green leaves and gives no evidence of having the frequent setbacks to growth that are general among its associates; *Fouquieria macdougalii* (Fouquieriaceæ), an ocotillo with solid massive stems and drought-deciduous leaves; *Idria columnaris* (Fouquieriaceæ), which has a stout trunk filled with lacunæ; and *Elaphrium microphyllum* (Burseraceæ), a tree with greatly enlarged cortex near the base of the trunk.

In eight samples of *Forchammeria*, taken from four trees in two localities, the moisture content varied from 47.5 to 60.6 per cent. When adjacent samples were taken from the same limb, the section from nearest the base of the tree had a slightly higher moisture content. In six samples of *Fouquieria*, taken from two trees 10 miles apart near the northern limit of its distribution in the vicinity of Carbo, the moisture content had a range from 62.5 to 67.7 per cent. The only material available for determinations on *Idria* was obtained at Cirio Point, 9 miles south of Port Libertad. Cross-sections of the entire trunk were taken from a tree 10 feet high, and on a 20-foot tree sections were taken at 7 and 14 feet. In each case the samples were 1 foot long. Additional determinations were made from pieces of the growing tip. The latter had a moisture content of 72 per cent, while the trunk sections varied from 78.7 to 80.9 per cent, in spite of the fact that the tips had much smaller lacunæ and pith than the stem. It was necessary to keep these samples in the oven for 30 days to bring them to constant weight. Four sections of *Elaphrium* were taken from four trees with a height of 6 to 8 feet and a trunk diameter of 12 to 14 inches. The samples varied from 60.9 to 70.4 per cent in moisture content.

The wood samples used in the above determinations were all collected in March and April at the end of the winter rainy season, which in this instance was a relatively dry one. None of the plants had received more than 4.50 inches of rain during the preceding 6 months. Although the four trees investigated belong to the class commonly designated as drought resisting, it would seem that they might be more properly called "drought escaping," in view of the relatively large quantity of water which they contain.

They are to be contrasted with the sahuaro, *Carnegiea*, in which the moisture content varies from 90 to 96 per cent.

Further work with these trees will be required for a full interpretation of the few data that have been secured. The soil and atmospheric conditions of the desert are such as to lead to the expectation that these trees would have a lower range of moisture content than mesophytic trees. There is a much greater mass and continuity of growth on the part of the mesophytic tree, while the metabolism of the desert tree is proportional to the amounts of water available in the various seasons.

ECOLOGY

ADAPTATION, BY F. E. CLEMENTS, FRANCES L. LONG, EMMETT MARTIN

The studies in the field of adaptation are concerned with two intimately related problems, namely, the production of new forms by the impact of such direct factors as water, light and nutrients, and the convergence or conversion of species belonging to the same evolutionary series. By virtue of the cumulative action of the new habitats from year to year, the number of conversions in the transplant gardens rises steadily and now embraces a dozen genera. Such changes are most readily brought about in paired species, by transferring the sun species to the shade and the shade form to the sun, or by exchange of alpine and plains species. As a rule, modification is slight or altogether lacking the first year; it becomes more or less definite during the second or third season, and the change is often complete by the fourth or fifth year.

As the most plastic of the genera employed, *Mertensia* has up to the present time yielded the largest number of conversions, in addition to many cases of convergence. The four major species, or *linneons* of Lotsy, bear the clear impress of their respective habitats and hence are sharply contrasted with each other. The circumpolar *Mertensia sibirica* is evidently the ancestral form, growing by preference along brooks in the forest edge. From this have apparently sprung the paired species, *pratensis* and *lanceolata*, the one adapted to the shade of spruce forests, the other to full sunshine in meadows at the same altitudes. The origin of *M. alpina*, a typical dominant of the alpine tundra, is less manifest, though the mutual convergence between it and *lanceolata* under experimentation suggests a direct evolutionary connection with the latter rather than with *sibirica*. After four years of exposure to a light intensity of 12 per cent in the lath-house at the montane gardens (8000-foot altitude), all the individuals of *lanceolata* have been converted into plants indistinguishable morphologically from the controls of *pratensis*. The reciprocal change is less complete, though most of the sun plants of *pratensis* closely approximate *lanceolata* and some of them are essentially identical with it. On the other hand, while a number of striking forms have been produced from both *sibirica* and *alpina*, conversion has proved a more difficult task. The former has been brought close to both *pratensis* and *virginica*, and some individuals in the sun garden have been altered into forms little if at all distinct from *paniculata*.

Other conversions obtained for the first time are those of *Senecio cernuus* into *S. bigelovi*, of *Solidago nana* into *S. humilis*, and of *Stipa viridula* into *S. minor*. An instance of exceptional interest was that of *Phleum alpinum*, in which cylindric spikes of the paired *P. pratense* appeared on one plant, along with the globose heads of the species. Among the striking convergences that give promise of becoming conversions in a few years was the transforma-

tion in shade of the alpine dwarf, *Senecio taraxacoides*, with single large nodding heads, into a stemmed form with several smaller erect heads. *Paronychia pulvinata*, an alpine cushion-plant with flowers and leaves at the surface of the soil, developed under shade into a form with slender leafy stems, closely resembling *P. jamesi* of much lower altitudes, while the similar circumpolar *Silene acaulis* underwent a like metamorphosis, to suggest one of the stemmed European species of the genus.

In the endeavor to secure as complete and graphic record as possible of modification and conversion, the dried specimens employed as vouchers are now being supplemented by portraits in color, water-color paintings and Kodacolor films by preference. Since these are both time-consuming and expensive, photographic prints tinted from the fresh voucher are utilized in considerable measure, especially for graduated series comprising four or five forms. To complete the record and to permit interpreting adaptation in terms of function, the histological changes involved are made available in the form of strips and films of the epiderm showing stomata and trichomes in particular, sections of the leaf exhibiting the relations of palisade and sponge tissue, and of the stem to reveal the nature and extent of the supportive and conducting systems.

The quantitative study of the water and light functions concerned in adaptation has been continued with reference to transpiration and osmotic values on the one hand and to the production of material on the other, against the usual background of recording instruments at the several gardens. The significance of soil temperature in the transpiration and growth of alpine dwarfs has been further tested by means of sunflower phytometers subjected to a temperature series of 35, 45, 55, 75 and 100 degrees F. These were arranged in metal troughs sunken in the ground and insulated above so that the humidity and temperatures about the shoots were essentially the same as for the controls. The rate of transpiration rose rapidly from 35° to 55°, but the higher temperatures were without appreciable effect; those below 35° regularly produced marked wilting, but in all cases turgidity was promptly restored by a rise of 10°.

To measure the effect of total radiation on the rate of water-loss, batteries of four sunflower phytometers were subjected to six different light intensities, provided by square screens of cheesecloth of progressive thicknesses. Measurements of the energy transmitted were made by means of the Abbot pyranometer and the values found to range from 10 to 80 per cent of full sunlight. Since air movement was not impeded, the other physical factors differed but little for the several batteries, though leaf temperature increased about 6° from the densest to the lightest screen. Reducing the radiant energy from 100 to 10 per cent diminished the transpiration to about 40 per cent, the results obtained on different days being fairly comparable. With respect to the concentration of cell-sap under the various conditions for adaptation, osmotic values yielded a good positive correlation with light and nutrients, and a negative one with water-content.

The production of material by forms of the same species grown under different conditions was measured for the entire period of growth in terms of dry weight and total calories per plant, and at fixed intervals in amounts of sugar found in the leaf. The combustion values have been secured by means of a Burgess-Parr bomb calorimeter and are expressed in gram calories. A score or more of species were utilized, but the results for two or three may be taken as representative. With water-content and nutrients equalized, *Campanula medium* gave the following combustion values in percentages for

sun, 12 and 4 per cent light intensity: 100, 10 and 5 per cent. In the length-of-day tents where the exposure to sunlight was for 14, 10 and 5 hours, respectively, the corresponding percentages were 100, 65 and 50. In the competition cultures where water and light are both concerned, the values yielded by *Plantago lanceolata* in planting densities of 4, 16, 64 and 128 per square meter were 100, 54, 27 and 4 per cent. The series of soil-pits with various dune-sands afforded the following results for *Helianthus annuus*: garden control, 100 per cent; stable sand with vegetation, 23 per cent; blow sand, 10 per cent; fore-dune sand with high salt-content, 3 per cent. In practically all cases, there was marked correlation between combustion values and stem height and width, size and number of leaves, color and size of flowers, kind and amount of pubescence, but in general the most striking modifications of specific criteria occurred in the light series and in the dune gardens.

In the attempt to correlate light intensity more closely with the results obtained in the adaptation and transplant gardens, the picric-acid method for total sugars in the leaf has been employed with increasing satisfaction. Its great accuracy with standard solutions is more or less reduced with leaf extracts when these require clearing, but in comparing forms of the same species this process appears unnecessary and this error is largely eliminated. In a test of the quadrants of four leaves of sunflower, the values in milligrams per square centimeter were in exact accord, with the exception of a single quadrant out of the sixteen. The error arising from translocation has further been minimized by the use of special tents that permit the exposure of single leaves or shoots to sunlight while the plant remains in a reduced intensity of known value. In the case of sun and shade plants of the same species, it can not be assumed that translocation proceeds at an equal rate, but the fact that sun leaves regularly give values 2 to 5 times higher permits good correlation with growth and reproduction.

CLIMATE AND CLIMAX, by F. E. CLEMENTS AND E. S. CLEMENTS

Further studies in the synthesis of climate, climax and succession have emphasized the paramount significance of the great grassland formation of North America. This is not merely because of its extent and complexity, as well as its exceptional value as a climatic and disturbance indicator, but also because the concepts and methods of dynamic ecology have been chiefly wrought out in it. During the field work of the past decade, it has been demonstrated that all the associations of the grassland climax have been much modified by human coactions, and a consistent effort has been made to reconstruct them in the light of the changes brought about by grazing, drouth, fire, cultivation and rodent populations. During the past summer, this effort was directed especially to the reconstruction of the true prairie as it existed before the period of settlement in the first half of the Nineteenth Century, and for this purpose a special reconnaissance was made through this region in Nebraska, Kansas, Missouri and Oklahoma.

Today in the remnants of true prairie left by cultivation, the three widespread species of *Andropogon* appear to be the major dominants. However, this rôle is apparent rather than real, and is due primarily to the exceptional vigor that has enabled them to withstand or profit by disturbances of various sorts. The scrutiny of many hundreds of relict areas disclosed that other dominants, such as *Stipa spartea*, *Koeleria cristata* and *Bouteloua racemosa*, must once have played a more or less regular part throughout, while one, *Sporobolus asper*, still ranks close to the chief *Andropogon*, *A. furcatus*.

Sporobolus is easily overlooked, since it normally blossoms in late September or in October, and the usual practice in mowing cuts it down before the flower-stalks appear. By virtue of their early blooming, *Stipa* and *Koeleria* are likewise inconspicuous during the summer, but in addition they have suffered an actual diminution. The chief factor in this has been grazing, since these species have long borne the brunt of the heavy spring demand for forage, on account of their earliness. Burning in the spring-time is also more injurious to such bunch-grasses and hence plays some part. Both processes throw the balance in favor of the chief competitor of these grasses, namely, the sod-forming *Poa pratensis* which makes its maximum demands at the same time, and also to a somewhat less extent to the advantage of *Andropogon* and *Sporobolus*. So definite are such relations that the degree of dominance of these three genera serves not only as an index to the period of human occupation, but likewise to the corresponding pressure on the original prairie.

During this expedition through the southern half of the true prairie, an exceptional opportunity was afforded to witness the actual conversion of tall-grass prairie to short-grass, in addition to the manner in which buffalo behave while grazing. This occurred in central Oklahoma on the Wichita National Forest, which is primarily a grazing reserve. The buffalo herd straggled like cattle on an open range, moving forward slowly but steadily as it grazed and leaving behind it a mosaic of partially cropped tall-grasses with frequent mats of buffalo-grass. The rate of recovery in such grazed areas was graphically demonstrated by the enclosures that had been installed. One area grazed by the herd from April to July was then enclosed; by September it had become so completely regenerated as to be practically indistinguishable from the ungrazed cover. The rapid recovery of true prairie under protection was also strikingly shown by an old pasture that had been reduced to a short-grass turf of *Bulbilis* and *Bouteloua* interspersed with relicts of tall-grasses. A fence was run through this in April to exclude cattle from one half, and by September this portion was again largely dominated by tall-grasses. Taken together, these facts seem to dispose conclusively of the assumption sometimes made to the effect that the short-grass subclimax of the Great Plains owes its genesis to the migratory herds of buffalo during the period preceding settlement.

The reconstruction of the prehistoric grasslands has cleared the way for the interpretation of the effects of major climatic changes during Recent time. In the furtherance of this project, a transect has been traced from the Ozark Plateau in Missouri and Arkansas through the forest ecotone and true prairie of Oklahoma into the mixed prairie of New Mexico. The Plateau is today covered by an oak-hickory climax, but its earlier composition is indicated by the presence of chestnut oak, sugar maple and beech in the deep valleys. A major climatic shift toward dryness handicapped these mesic species in the competition with the more xeric oaks and hickories and has permitted their survival only as relicts in moist lowlands. A similar process has operated at the edge of the Plateau, where the rainfall is lower. Under progressive desiccation, the original oak-hickory forest has shrunk back into the valleys and on to the high outliers where a more favorable water-content permits its persistence. At the same time, the mesic oaks have withdrawn into deeper canyons under the protection of moister local climates. Westward over the rolling plain the trees have everywhere retreated from the hard soils and found refuge in the frequent sandy areas derived chiefly from Permian sandstones. In these the available water-content is much higher and the competition of grasses much less effective. However,

the climate is semiarid and only the most xeric oaks, such as *Quercus stellata* and *minor*, remain as relicts. Even these are much reduced in stature so that they constitute a savannah in which the climax dominants are grasses. This effect of a progressively drier climax increases to the westward, until on the high plains the oak savannah is dwarfed to the so-called "shinry," consisting of bush-like forms but a foot or two high.

Further proof of the former presence of the deciduous forest in this region is furnished by isolated river gorges, of which Caddo Canyon is an outstanding example. This is a narrow cleft in the White Horse sandstone, 100 feet deep, in which the shade of the walls, the sandy soil and the meandering stream constitute an ideal refuge. The relict community that survives here contains sugar maple as its chief species, nearly a hundred feet tall, and associated with equally tall bur, red and yellow oaks, coffee-tree, mulberry, red-bud, etc. The significance of such relicts is even more eloquently attested by the presence of the yellow oak (*Quercus muhlenbergi*) in deep canyons of the Capitan and Guadalupe Mountains of New Mexico, 300 miles farther to the west, but with no intervening stations.

Investigations into the number of animals, their rôle in the climax, their reactions upon soils especially and their coactions with each other have continued through the year in cooperation with Dr. Taylor and Dr. Shelford. In collaboration with the latter, the field of bio-ecology has been organized and developed on the dynamic basis, and it is hoped that the book embodying this treatment may be issued before the end of the year. The reactions of animals in initiating or supplementing erosion by wind and water have received increasing attention in the field and have assumed an important part in the cooperative studies of erosion and water-supplies with the Forest Service and National Park Service. In connection with the control and manipulation of the various biotic climaxes, these constitute an important beginning in the field of experimental succession, with the promise of novel scientific and practical results.

PALEOBOTANY

RESEARCHES BY RALPH W. CHANEY

The study of the Tertiary floras of western North America has been continued during the past year with the cooperation of Dr. E. I. Sanborn of the Oregon State Agricultural College, and with the assistance of several students of paleobotany at the University of California.

The Eocene floras of western Washington are being studied by R. S. LaMotte. Mr. LaMotte has made extensive collections and is assembling stratigraphic data by which it should be possible to correlate these well-preserved floras with those in the eastern part of Washington and with the floras of Oregon, California and Alaska. In Oregon, collections have been made by E. I. Sanborn and R. W. Chaney at a new locality near Goshen; the first of a series of papers on the Goshen flora has been published and additional papers are in preparation which are designed to establish its age and the physical conditions under which it lived. Fossil plants have been collected by S. S. Potbury at LaPorte, California, and her study of this material is sufficiently advanced to indicate a relationship with older Tertiary floras and with the modern forests of Mexico and Central America.

The Miocene plants from Trout Creek in southeastern Oregon have been studied by H. D. MacGinitie. The vegetation bordering this middle Tertiary lake, as represented in his collection and those of Percy Train, is of the same general type as that now occupying the Klamath Mountains of

southwestern Oregon and northwestern California, and also shows relationships with the cool-temperate modern vegetation of northeastern Asia. A flora of similar composition from Forty-nine Camp, in northwestern Nevada, is being studied by R. S. LaMotte who has made a large supplementary collection with the assistance of Carleton Condit.

An important collection of Pliocene plants from the Eden beds in southern California has been turned over to us for study by Mr. Childs Frick, under whose direction this material was secured. Association of these plants with fossil vertebrates, and their suggestion of the cool, semiarid climate indicated by other Pliocene floras in the interior of California, make this flora one of the most significant which is known from the later Tertiary of western America.

The study of the Pleistocene floras of California has been continued by Dr. H. L. Mason of the University of California. His work on the Tomales flora from the coast of central California has been completed, involving the discussion of 50 species and a consideration of their distributional significance in relation to the closely similar closed-cone pine forests of coastal California. A discussion of the flora from the asphalt deposits near Carpinteria has been published under the authorship of Dr. Mason and R. W. Chaney, and a paper on a flora from San Bruno by S. S. Potbury has also been published during the current year.

The study of fossil wood has received little attention from American paleobotanists, due in large part to the difficulties involved in its proper identification. The work of Dr. I. W. Bailey, as discussed elsewhere in the report of the Division of Plant Biology, is throwing critical light on certain of the coniferous woods from western America. Dr. Bailey is also assisting in an important way the studies of dicotyledonous woods which are being carried on by L. H. Daugherty. Mr. Daugherty is attempting to develop an accurate basis for distinguishing the woods of modern American dicotyledons, and to apply these criteria in the determination of the abundant specimens of Tertiary wood which he is studying.

Field work by R. W. Chaney in northeastern Asia will be more fully discussed in the report for the year 1933-34. It involved (1) a study of the occurrence of *Sinanthropus* at Choukoutien and the collection of plant fossils from the horizons in which early Man has been found; (2) the collection of a Pliocene flora at Taiku, Shansi Province, and a study of the modern vegetation; (3) the study of the older Tertiary flora in the oil shales at Fushun, Manchukuo; and (4) visits to the modern forests in the mountains of Chosen and Japan in which there are associated many of the genera found in the middle Tertiary floras of western America, and whose range has been greatly restricted subsequently. Preliminary papers have already been written on the Taiku flora and on a piece of wood referred to *Cercis* from Choukoutien. A preliminary paper has also been written on a middle Tertiary flora from Uganda in central Africa, and additional material of Pleistocene age has been sent in through the courtesy of Mr. E. J. Wayland, director of the Geological Survey of Uganda.

CYCADEOID INVESTIGATIONS

By G. R. WIELAND

In the Year Book for 1930 reasons for regarding angiosperms as being as old as conifers were briefly outlined. There had come into view in a single day as it were, after a search that had extended through quite twenty-five years, the imposing series of cycadeoids from the San Juan basin freely

illustrating the types with small flowers in all leaf base axils. There was seen for the first time in fuller alignment in a greater fossil gymnosperm group, a flowering as profuse as that of monocotyledones, or of hardwood trees, or of pines. Moreover, those small complete flowers in the axils of all leaf bases seemed then and still seem to suggest an ancient type become specialized. That is to say, taking into account the fact that within the cycadeoid alliance there is found both free branching in slender stems and yet smaller flowers, it at once became necessary to go back at least as far as older Pteridosperm times to account for the origins of floral types in general. The greater lines of seed plants were all floral.

The conifers it was thought must mainly be a secondary and inflorescent, rather than a truly primitive, group ancestral to later floral types. The basis for this view depended on a study of the remarkable Araucarian series of the Field Museum from Patagonia, on studies of present-day cones, amphisporangiate and mature, and on what was considered to be the general result of the botanical study of cone constitution which had gone on for just about one hundred years. At present there seems to be no reason to greatly modify the views of floral origin from time to time set forth during the longer course of cycadeoid investigation.

A restudy of the wood structure of the entire cycadeoid group (including European and Asiatic as well as American types) shows it to be a unit. The wood is mainly scalariform throughout, and very close to that of the homoxylous angiosperms. Moreover, it is very easy to see how the wood of the angiosperms in general has arisen from such older scalariform types. Nor is foliage or flower in the way. To repeat, in accounting for the origin of the cycadeoids we are driven far back into Pteridosperm times, and quite possibly, as Seward would also hold, into Pteridosperm relationships. There one might even look for the origin of the angiosperms as well. The conifers go back to those times too, and they were always floral in a high degree. They do suggest approaches toward angiosperm structure. But they early became aplastic as far as may be discerned, whereas the more characteristic cycadeoids were not only plastic in habitus, in wood, in foliage, but, so far as analogy goes, in their floral structure. It is among the latter rather than the conifers, therefore, that in Permo-Carboniferous times the more defined angiosperm antecedents (in so far as not discrete) should first be sought for.

We see that the free-fruited, heavy-stemmed cycadeoids extend from the close of the Jura well on toward the close of Cretaceous time, with also wide geographic distribution. But whether as supposed this is the older and more characteristic section of the heavy-stemmed group or not, cycadeoid study in general has been given a marked impetus by the assemblage of the Mesa-verde series. In fact here is the key to study of the heavy-stemmed types. Because of the uniformity in the complementary floral series, both thin and thick sectioning take on a completeness not before seen. Particularly good are the serial sections cut through the cortex to show the origin and course of both leaf and peduncle bundle. Also, in the course of these later studies the methods of preparation have been markedly improved. Hitherto, there has been much reliance on thin sections, always difficult to prepare if of large size or from dense material; while it was thought generally necessary to polish all larger or thick sections in order to bring into view such features as might be present. During the work of the past year, most of this extra labor of preparation has been dispensed with. Etching with hydrochloric acid for calcified materials and with hydrofluoric acid for silicified structures has often been found so effective that it may well be said that thin sections, while of great use and often of a surpassing beauty, are as taken by themselves a

thing of the past. In some of the thick sections cut through *Raumeria* fruits and then etched, the results are far finer than any that could be had from any thin sections. In this work I have had some aid from Professor Fredda D. Reed of Mount Holyoke College and she has shown, in the instance of those finer silicified gymnosperm stems with residual carbon, that but few descriptions may be thought complete without further study aided by etching of polished surfaces.

This use of etching extends to the larger sawcuts of all sizes, of which many have been cut in the study of the Mesaverde group. In these types the freshly sawn surfaces are sometimes light of color, sometimes dark. But whether of one tint or another, by the combination of etching and retouching fluids such as are used in facing old paintings, or again by the use of shellacs (with or without polishing), the structures may usually be brought up on the rough saw cuts quite as effectively as by any course of polishing alone. Though certainly if surface polishing precedes etching, clearness of pattern may often be heightened. Drawing in of structure features on these treated surfaces previous to their photography is done with complete accuracy, and has already resulted in a series of illustrations of an excellence hardly reached in our previous work. One should be cautioned that in certain dark specimens addition of a retouching fluid direct may so darken the texture as to quite blot out the structure; but in such the hydrofluoric etching is often effective by itself.

CLIMATOLOGICAL RESEARCHES

By A. E. DOUGLASS

COAST REDWOODS

Study of the large collection of coast redwood sections secured in 1931 has been continued during the past year. Mr. Edmund Schulman has conducted the dating comparisons and the measurements upon the wood. He has succeeded in cross-dating between different trees by means of occasional deficient rings. These are found to supply a check on the accuracy of the counting even though fewer in number per century than in the case of the pines of Arizona. Thus a sequence of excellent dating has been carried back several hundred years, and there is hope of reaching essential precision in counting the rings of about one-third of these difficult trees.

Mr. Schulman has found that this cross-dating is better in the upper levels of the tree than at the base, which confirms the estimate made in the summer of 1931 at the time of collection. He has found that the occasional small ring used in the cross-dating referred to above in many cases corresponds in date to a small ring in the giant Sequoia and other trees of the Sierra Nevada, as for example 1924, 1887, 1846, 1777, 1748, etc.

About 35 radials in 21 different trees have been measured and analyzed for cycles. Of these radials 22 in 14 trees are dated and the others, with two exceptions, are regarded as less than 2 per cent in error. It is important to note that upon cycle analysis by Mr. Schulman, the dated and undated specimens, arranged in separate groups, agree well with each other and match in a satisfactory manner previous analyses of Western pines and fossil redwoods referred to below.

CLIMATIC INTERPRETATION

Especial attention has been given to the relationship between tree growth and rainfall in the Colorado Plateau area of northern Arizona and northern New Mexico. The rainfall records in this area are generally short but there

is a similarity one to another over the area studied. When these curves are taken as a whole there are many maxima that agree with tree growth maxima, but the best agreement is found in the minima. It is generally felt that in these cases where a physical connection is logical and yet complex, the usual correlation coefficient is not sufficient, as it is not so well adapted to varying conditions. Dr. Dinsmore Alter has brought out the fact that in applying his correlation periodogram to tree values there is a strong correlation in lags of 1, and 2 and 3 years; that is, the correlation coefficients between tree growth curve and the same curve with a lag of 1 year to 3 years are high. On more careful examination, he found this lag to be largely confined to the maxima of the growths and to be deficient or absent in the minima. This at once confirmed our long-time use of the minima in cross-dating which has been the standard method since the discovery of cross-dating in 1911.

Perhaps the most pertinent interpretation problem can be stated in the form of a question: What is the climatic element that makes cross-dating possible? The marked success of cross-dating in the semi-arid Pueblo area points to moisture as a very strong factor. The high correlations in the maxima for small lags is undoubtedly some form of conservation. It directs our attention forcibly toward some method of expressing similarity in the minima, for the purpose of developing some possible coefficient or index of cross-dating.

Accordingly another expression dealing with relationship between tree growth and rainfall is now being studied, derived from skeleton plots, so called because they represent deficient or drouth years only. Each year that appears as deficient in the skeleton plot is expressed as a percentage of the mean of the adjacent years. These deficient years in the trees all therefore receive numbers less than unity. The corresponding years in the Plateau rainfall are treated in same way, and if deficient will become expressed by quantities less than unity; if they disagree they will be more than unity. In five group curves tried the agreements occurred in nine cases out of ten.

We are making use of another mode of expressing the relationship between two curves. This is a trend test leading to the "scatter" diagram and worked out in this case by Dr. W. S. Glock. In this process the algebraic increments in each curve from year to year are used. The increments of one curve are plotted as abscissæ and those of the other as ordinates. If the relationship is evident, the group of dots approaches a diagonal straight line. This is the common "scatter" diagram. Pairs of values from the two curves may be multiplied together to give results in quantitative form. The sum of the positive products divided by the total sum of positive and negative gives an index of agreement. Expressed in this manner two tree curves, Pinyon, in the center of Black Mesa, and Fort Defiance, 70 miles apart, had 96 per cent agreement index. The Fort Defiance curve has 81 per cent compared to Flagstaff-Prescott rainfall.

At the invitation of the Carnegie Institution, Dr. Alter spent a week at Tucson in examining the cyclograph method of analysis. This he recognized as a graphic correlation method of great rapidity and flexibility and specially adapted to the pursuit of fragmentary climatic cycles.

CYCLE STUDIES

The cyclogram method of analysis was developed in 1913 and 1914 and applied at once to tree records. It was realized that in the cyclogram we have a means of studying and analyzing climatic variations that enables us to see cycle variations even if temporary. During the years from 1914 to

1931, the discontinuous cycle was fully realized, and yet its real significance was not visualized. In the spring of 1932 the evidences of climatic cycles in the various tree-ring records were gathered together. In discussions and contacts at that time it was realized that in climatic cycles we are dealing with a different type of change to which the methods used so successfully in studying the permanent astronomical cycles can not well be applied. For example, in determining an astronomical cycle by harmonic or other accepted mode of analysis, the longer the series of observations the more certain and definite is the result, but if we are dealing with discontinuous cycles and temporary variations it is quite evident that the same methods of analysis will become less and less determinate with longer intervals, for since the cycle is only temporary the moment the data ran past the end of the cycle, the cycle tends to disappear and its existence becomes less and less evident.

A most important development in the past year is the realization of the difference between astronomical cycles and temporary or astro-physical cycles, such as occur in climate and sunspot numbers. Accordingly, attention has been directed especially to finding relationship between climatic cycles and solar cycles of this discontinuous type. In general features they contain similarities, but there are there major points of agreement:

(1) Climatic records in trees and in limited areas of rainfall show a group of cycles including one somewhat over 11 years in length that in some localities shows one crest and in others two, in which latter form it is called the "Hellmann Cycle."

(2) The eleven-year plus cycle which has been common in trees since 1400 A. D. was absent during an interval of time, approximately 1650 to 1725. Historical studies by Spoerer, E. W. Maunder and Mrs. Maunder show that during that interval sunspots were nearly always absent, so that Maunder called the interval from 1645 to 1715 the great "dearth" of sunspots.

(3) A study of more than 50,000 measures on 305 western trees completed in 1926 shows a complex of cycle lengths, consisting mostly of 8+, 10, 11.4, 14, 17, 19 or 20 and 23, and other longer ones. Essentially the same group of cycles is found in the study of various trees which must have been living 2000 to 5000 years ago, also in the fossil Sequoias of the Yellowstone National Park, also in certain anhydrite layers in Texas, and recently in the coast redwoods.

From analysis made by Schuster and checked by the cyclograph we find evidence that solar records contain a complex of cycles very similar to the list just mentioned. The hint in this of stability in the sun is likely to prove of significance in astronomical studies.

While we then seem to be building a picture, from terrestrial sources, of something going on in the sun we recognize the immense gaps in physical sequence. We know that heat from the sun reaches the earth, but there are great problems in connection with its effects on terrestrial temperatures and atmospheric activity. The distribution of this energy about the earth is enormously complex and will take years to unravel. Finally there is the very difficult interpretation of the trees' reaction to a complex environment.

CLIMATIC RECORDS IN THE SOUTHWEST

Especial emphasis should be placed on the climatic value of long tree records. While the climatic interpretation of ring widths is still crude and undeveloped, there is abundant evidence to show that the ring records on the Colorado Plateau do supply data upon rainfall variation. As such they are perhaps the best material yet developed for the study of these longer climatic cycles.

A part of the work of the past year has been devoted to the extension of tree-ring chronology in the dry climate of the Colorado Plateau. Mr. E. H. Morris made most important collections in 1931. These have been worked over largely by Dr. Glock, and reviewed by the writer. In 1932 Mr. Morris collected another important group from the same general area in north-western New Mexico. His specimens have developed two chronologies, the first of which was known as EPD, discovered in 1927, and the second known as JCD, discovered in 1930. These were both found also in Mr. Morris's collections from certain parts of Mummy Cave. During a brief review in the past year they were joined and gave a sequence over 800 years along, which must rather largely antedate the present known sequence that goes back to 643 A. D. (The extension from 700 A. D. to 643 was made by Miss Florence M. Hawley, on a specimen obtained in Chaco Canyon late in 1931, in connection with work of the University of New Mexico.) A possible connection between this long early sequence and the actual dated rings, indicating a considerable overlapping, is now under investigation.

STAFF

During the past year Dr. Glock has entered extensively into the computation of correlation coefficients and other data needed in the study of cycles in trees and their relation to rainfall and to the solar cycle. At the same time he has reviewed completely the collections mentioned, secured by Mr. Morris. He has prepared a manuscript on tree-ring manipulation and especially he has worked upon the curves of rainfall and tree growth along the Colorado Plateau.

Mr. H. F. Davis has made extensive reductions on the Swedish collection of 1930 and has assisted most helpfully in photographic work connected with researches mentioned above.

Mrs. Gertrude Dewey has made the complete reductions of a very important group of pines from the San Bernardino Mountains and is still engaged upon the study of cycles and other characteristics in them. The value in this collection lies in the resemblance of their growth increments to the rainfall of neighboring regions of Southern California. This work has been generously financed by the Bear Valley Mutual Water Company, of Redlands, California, and its president, Mr. J. J. Prendergast.

Mr. Schulman has worked on the coast redwoods and has also cross-dated, measured and prepared tables of ring growths of several fine groups of pine secured in the Great Basin in northern California and southern Oregon by Dr. Isaiah Bowman and Dr. E. Antevs.

DEPARTMENT OF TERRESTRIAL MAGNETISM¹

JOHN A. FLEMING, ACTING DIRECTOR

GENERAL SUMMARY

Effort has been chiefly concentrated during July 1, 1932, to June 30, 1933, as in the previous year, on the study of the extensive observational material in hand, particularly that obtained on the last cruise of the *Carnegie* and at the Department's two observatories, rather than to the amassing of new data. However, the Department has taken an active part in the inauguration and maintenance of the two American Polar Year stations at Point Barrow and College-Fairbanks, Alaska, and has collected data for secular-variation studies at a number of repeat-stations in South America.

Bartels and his assistants have been engaged on the determination and analysis of the magnetic lunar diurnal-variation from data for the Watheroo and Huancayo magnetic observatories, and special harmonic analyses of the diurnal variation on the western hemisphere are being studied by McNish.

The Department's program in the laboratory on the basic phenomena of magnetism has been directed in recent years toward a study of the simplest interactions of the fundamental material particles of which all matter is composed. A conference on this research-program was held at the Institution in October 1932, giving the Department the benefit of the suggestions and advice of a group of outstanding investigators. The basic constituents of matter are now known to have important magnetic properties which supplement the electric forces by which they were previously known to interact. Tightly bound together to form the nuclei of atoms of the chemical elements, large energies (on an atomic scale) are required to separate these basic particles in a study of their interactions, and the high-voltage methods described in previous annual reports have been used during this report-year to disintegrate some of the lighter atomic nuclei, yielding information on the energies involved in these particular configurations of the primary particles. For these experiments a one-meter (600 kilovolt) electrostatic generator of the type devised by Van de Graaff was used with the cascade-type high-voltage tube described in the report for 1929-30. An addition to the laboratory designed to house the 2-meter generator (for higher voltages) was nearing completion as the report-year ended.

Experiments which verified the existence of the "neutron," which may be a new type of fundamental particle, were made several months after its discovery was announced in England. It is expected that the 2-meter generator can be used to produce a comparatively strong source of neutrons, which will make possible a study of the properties of this new particle. Search is under way for the one-quantum isolated magnetic poles predicted by Dirac in 1931. Proof of the existence of isolated magnetic poles would be of transcendent importance in physics; obviously nothing could be more fundamental to the study of magnetism.

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A study of the factors which limit the measurement of very small electric currents showed that the FP-54 vacuum-tube attains the theoretical limit of accuracy which is set by the thermal agitation of electric charges (in all materials) at room-temperature.

The magnetic, atmospheric-electric, earth-current and meteorological programs at the Watheroo and Huancayo Observatories, and the cooperative work in atmospheric electricity with the Apia Observatory, and in atmospheric electricity and earth-currents with the Tucson Observatory of the United States Coast and Geodetic Survey, were maintained. Equipment for special registrations of magnetic phenomena during the International Polar Year was installed at the Watheroo and Huancayo observatories. Apparatus for the study of variations in the ionized layers of the ionosphere was completed and received at Huancayo and at Watheroo. This equipment was installed at Huancayo and results were being obtained there in June 1933, while the equipment had arrived at Watheroo and was in course of erection there. Several months' continuous photographic records of the ionization due to penetrating-radiation, beginning October 1933, at Huancayo, afford evidence of a diurnal variation of the order of one to two per cent. Effect of thunder-storms of the order of one per cent was noted, with "bursts" appearing when these storms were more than 15 kilometers distant. It is perhaps significant that thunder-storms to the west of the Observatory seem to have more effect on the ionization than those to the east.

As an outgrowth of the activities reported last year, continuous registration of earth-currents is now being made at a total of eleven stations, all of which will continue throughout the Polar Year, while at two additional stations the registration will be continued for periods just long enough to disclose the value of diurnal variation.

Although magnetic operations in the field have been limited by necessary curtailments, the accumulation of data for secular variation has progressed steadily, and the results verify in a striking manner previous conclusions as to its regional characteristic and variable acceleration. The analysis of existing data has gone on, particularly that of the *Galilee* and the *Carnegie* in the Pacific, and from land-observations in the vicinity of the rapidly changing isopors in the Caribbean area.

Excellent progress was made both at the office and by cooperating agencies in the reductions and compilations of the work in physical and chemical oceanography, and in marine meteorology, depending upon observations made during the last cruise of the *Carnegie*. The manuscript for these compilations and discussions is about 90 per cent completed, and the first volume of results with tabulations and their representation for interpretation by numerous graphs will be ready for publication by the end of 1933.

The Department has been deprived of a valuable member of its staff in the death, December 26, 1932, of Harlan Wilbur Fisk, chief of the Section of Land Magnetic Survey. Since joining the Department October 1906, he had centered his activities chiefly on land-magnetic survey work, taking part in the field as well as in the office, and in training many of the Department's most successful observers. In his later years he had charge of the extensive magnetic survey effected by the Department in all parts

of the world. His chief contribution to research in terrestrial magnetism resulted from his investigations of secular changes and of the shifting of isoporic foci disclosed by the magnetic survey. His last work was devoted to the investigation of the possibility of determining changes within the Earth's crust or interior through the study of magnetic observations obtained on its surface.

INVESTIGATIONAL AND EXPERIMENTAL WORK

TERRESTRIAL MAGNETISM AND ELECTRICITY AND COSMICAL RELATIONS

Variability of magnetic diurnal-variation—The important bearing of the magnetic diurnal-variation upon phenomena in the upper atmosphere has been recognized and investigated, in the past, by discussing nothing but the average diurnal-variations as calculated from a number of days, for example, all quiet days in a certain month. This restriction to averages, however, blocks the way to a full understanding. Generally speaking, the basis for a theoretical explanation of a geophysical phenomenon is a complete summary of the observations; such summary is incomplete if the statement of the average value or appearance is not supplemented by an account of the variability of the phenomenon. For instance, the daily readings of the air-temperature, taken at fixed hours at a given station, are only partially summarized in the monthly average temperatures; for a climatological discussion, additional information on the variability is needed, for example, on the frequency, duration and intensity of hot and cold spells.

Adequate expressions and modes of description for the variability have long been derived in general statistics and applied in geophysics. They are, however, mostly applicable only in such cases in which each observation can be expressed by one quantity (frequency-curves) or two quantities (theory of correlation), while these methods are not readily transferred to research on periodical variations, for instance, those with the period of a solar day.

In a series of papers, Bartels has developed general statistical methods for research on diurnal variations, together with schemes for numerical and graphical work suitable for handling the largest possible amount of material. The procedure has been applied to magnetic diurnal-variation at Watheroo and Huancayo observatories and has already yielded convincing results. Thus, the diurnal variation of declination at such an equatorial station as Huancayo is found to vary considerably even on very quiet days. At Watheroo, on quiet days in southern summer, the horizontal intensity has, on the average, a small diurnal variation, because Watheroo is situated in the transitional zone between the equatorial and the polar types of the variation; individual days, however, exhibit either the equatorial or the polar type quite markedly, indicating that the focus of the diurnal atmospheric current-system passes on some days several degrees of latitude south, on other days north, of Watheroo. Furthermore, the passage of the focus is retarded or accelerated on some days by a few hours, and the intensity of the current varies by a large fraction of its average

value; these features are indicated in simultaneous changes of the diurnal variations of declination and of vertical intensity.

Terrestrial magnetism and solar and cosmical phenomena—The above investigations are being continued by Bartels, especially with regard to possible interrelations between solar and lunar variations, which would be of great theoretical interest. In this way, the natural variability, instead of being regarded as an undesired feature which must be removed by averaging, will be made to serve for revealing the physical nature of ionization-phenomena in the high atmosphere.

Studies by McNish of the 11-year variation in the horizontal component of the Earth's magnetic field using data from the magnetic observatories at Bombay, Batavia, Cheltenham, Honolulu, Potsdam, Sitka and Tucson indicate that the correlation between the second differences of the mean annual values of horizontal intensity and magnetic activity is always negative and may be represented roughly as a linear function of the geomagnetic latitude, having large values near the geomagnetic equator and approaching zero toward the geomagnetic poles.

Magnetic activity—Investigations of various measures of magnetic activity were continued by Duvall and in particular of the measure adopted at Stockholm in 1930 by the International Association of Terrestrial Magnetism and Electricity—the so-called numerical magnetic character of days. The results indicate this measure is not altogether a satisfactory one for world-wide investigation of activity, as seasonal effects of varying magnitudes influence the values obtained by the method for stations differing in geomagnetic latitude.

The investigation by Peters of the distribution of sudden commencements over the globe was continued, and the results are shown in stereograms representing the direction and intensity of the field indicated by the first large movement for a number of storms.

Atmospheric ionization—Rates of ionization in a thin-walled vessel were recorded continuously by Wait and McNish during some six months in Washington. Variations of the daily rate were as much as twofold and there is also evidence of a regular diurnal-variation. The rate of ionization may increase several times during a thunder-storm. Screening of the vessel shows that the greater part of the ionization is due to radiations more penetrating than alpha-particles.

A full year's automatic records of large ions, eight months' records of small ions, and two months' records of intermediate ions have been obtained in the studies of atmospheric pollution during the past year by Wait and Torreson. These data represent the only known series of continuously recorded measurements of these elements. The character of the diurnal variation of large ions is shown to change with the season of the year. Comparison of simultaneous periods during January 1933 of diurnal variation of small ions with that of large ions shows a remarkable reciprocal relationship between the two elements, indicating that a knowledge of the large-ion content of the atmosphere is important to an understanding of the phenomena of terrestrial electricity.

Six months' registrations of atmospheric potential-gradient by Sherman at College-Fairbanks, Alaska, show the presence there in the diurnal curve

of a well-defined maximum at 18^h G.M.T., which is in excellent agreement with the results observed on the *Carnegie* and on the *Maud* expeditions.

Upper-air ionized regions—Regular measurements of the height of the ionized layers in the upper atmosphere were begun in June at the Huancayo Observatory. Reflections from the *E*- and *F*-layers have been observed, together with determinations of their virtual heights. A few series of determinations of critical frequency have been completed. Of particular interest is splitting of the echo from the *F*-layers on the higher frequency, due probably to magnetic double refraction—a phenomenon which has been observed in the United States at Washington and in England.

Instrumental investigations and improvements for work at sea—Numerous experiments have been made by Peters in the automatic swing for the purpose of correlating the amplitude of the card-oscillation with the corresponding deviation. It was found that the amplitude of the card-oscillation as observed by one lubber-line was affected by a sliding motion of the jewel cap upon the pivot. The influence of this motion is being investigated further.

Further theoretical consideration was given by Soule to the application of earth-inductor methods for measuring magnetic intensity at sea, and he began the design of the experimental equipment for investigation of this matter. Some attention was also given to the design of an electromagnetic magnetometer for use on land and sea for the simultaneous determination of total intensity, declination and inclination, as well as the design of a simple device to test the sensitivity of this proposed method. These studies and those on dynamic deviations are being pursued in the expectation that the results will be helpful in the solution of the problem of making magnetic determinations of precision from a moving support at sea.

Polar magnetic data—Extensive cooperation as elsewhere described was effected with the International Polar Year Commission to extend existing magnetic data in the Arctic and Antarctic regions. Ennis has taken up the compilation of the magnetic data obtained by Wilkes in his Antarctic expeditions early in the Nineteenth Century, utilizing for that purpose the original manuscripts kindly loaned by the United States Hydrographic Office.

MAGNETISM AND ATOMIC PHYSICS

EXPERIMENTAL

The laboratory program on problems related to the basic phenomena of magnetism was carried forward by Tuve, Hafstad, Dahl, Brown and Seidenspinner, with occasional assistance regarding instruments from the shop-personnel, particularly from Huff. This program at present is chiefly concentrated on studies of atomic nuclei, in which the primary particles are known to be bound together by magnetic as well as electric interactions.

Conference on magnetism and atomic physics—At the invitation of the Acting Director, a conference was held at the Institution on October 7 and 8, 1932, to assist him in determining the directions and the limiting boundaries within which the Department's work on fundamental problems, especially those relating to laboratory investigations, might most profitably be continued, by obtaining the suggestions and collective judgment of a group of investigators of wide experience. The following gentlemen were

in attendance: G. Breit of New York University (a research associate of the Institution), K. T. Compton of the Massachusetts Institute of Technology, F. G. Cottrell of the Fixed Nitrogen Research Laboratory, N. H. Heck of the United States Coast and Geodetic Survey, K. F. Herzfeld of the Johns Hopkins University, E. O. Hulburt of the Naval Research Laboratory, F. K. Richtmyer of Cornell University, H. N. Russell of Princeton University, and J. H. Van Vleck of the University of Wisconsin. Being unable to attend in person, letters and comments were contributed by J. Bartels of the Forsthoehschule of Eberswalde and of the University of Berlin, S. Chapman of the Imperial College of Science and Technology of London, B. Gutenberg of the California Institute of Technology, W. Heisenberg of the Institute of Theoretical Physics of the University of Leipzig, R. H. Fowler of the University of Cambridge, and R. Ladenburg of Princeton University. A similar conference, although somewhat more general in scope, was held January 20, 1922 (see Annual Report for 1922, pp. 268-270).

Following an inspection of the Department's laboratories and discussion in which every one took active part, resolutions (I) to (V) noted below were unanimously adopted; resolution (VI) was adopted, although there was a division arising from question as to whether the stated purpose of the conference included consideration of the broader aspects of research in atomic physics which that resolution represents.

(I) The conference notes with pleasure the thoroughly efficient spirit of cooperation on the part of all the members of the staff of the Department of Terrestrial Magnetism in forwarding all of its work.

(II) It is the sense of this conference that the recent work in nuclear physics of Dr. Tuve and his associates in the Department of Terrestrial Magnetism is important, has been carried on in commendable fashion, and has reached a stage at which discoveries may reasonably be hoped for in the near future.

(III) This conference heartily approves of the policy of frequent and informal conferences upon past and present work with other investigators engaged in research in atomic physics.

(IV) The conference believes that the efficient use of the high-voltage generator requires its adequate housing.

(V) The conference believes that the utilization of the large amount of accumulated data in terrestrial magnetism and electricity as well as the coordination with investigations in nuclear physics and cosmical radiation, whether made in the Department or elsewhere, would be aided by the appointment of a geophysicist specially trained in the statistical interpretation of observational results.

(VI) This conference understands that it is not within its province to express an opinion upon the questions of the extent to which research in general atomic physics should be carried on by the Carnegie Institution or of the auspices under which such investigations, if attempted, could most advantageously be made.

High-voltage technique—Lacking suitable housing for the 2-meter Van de Graaff electrostatic generator described in last year's report, a smaller generator adapted to the dimensions of the Experiment Building was constructed, and, following the conference in October above referred to,

the Tesla-coil equipment was removed and this generator installed. Two hemispherical shells, one meter in diameter, are fitted to a short cylindrical section which contains direct and alternating current generators, transformers and controls for the low-voltage arc ion-source (protons or helium-ions) at the end of the high-voltage tube. A 12-inch silk belt running 4000 feet per minute provides 200-microampere charging-current and drives the ion-source generators. Voltage-measurements of high accuracy have not been necessary to date, but approximate measurements have been made by four methods, namely, (1) generating-voltmeter (Kirkpatrick-Gunn), (2) sphere-gap, (3) magnetic deflection of ion-beam, and (4) range of high-speed protons. Of these methods, (3) is unquestionably the most reliable. All methods indicate that this generator as installed reaches a maximum usable positive potential of 600 kilovolts. Somewhat higher potentials seem to be obtainable with the sphere negative, but the generator has only been used for accelerating positively charged particles. Using one of the original cascade-type high-voltage tubes described in the report for 1929-30 with this generator, the highly satisfactory and valuable fact was established that with this design of tube the beam of positive ions admitted at the high-voltage end is *focused* down the tube. A 23-section tube, 175 cm. long, with spun copper-tube electrodes having 2-cm. holes at each end, focused ion-currents up to one-half microampere more than 50 per cent on to the target at the far end of the tube. Secondary electron-emission evidently prevented the use of larger ion-currents with the available charging-current of this generator. A 6-section tube with electrodes of larger diameter was constructed for larger currents, and although the focusing of this tube does not appear to be as good as that of the older tube, it has been used successfully for numerous observations and experiments without attempting modifications. It is interesting that either tube withstands the peak-voltage when containing mercury-vapor at room-temperature, if no ion-current is admitted, and a pressure below 1×10^{-4} mm. of mercury is not required for the highest ion-currents (10 to 20 microamperes). No parts of the new tube were out-gassed, and the "seasoning" period before withstanding full voltages and current was only three hours after the first assembly and 10 to 20 minutes after exposure to air at atmospheric pressure on successive occasions.

A special appropriation was made by the Institution in January 1933 for an addition to the Experiment Building to house the 2-meter electrostatic generator. This building was under roof and rapidly nearing completion at the end of June 1933.

Artificial nuclear-disintegration—Using the electrostatic generator and tubes above described, the disintegration of lithium- and boron-nuclei by high-speed protons, having energies from 200 to 600 electron-kilovolts, was first investigated. The disintegration of nuclei by high-speed protons was first observed in April 1932 by Cockcroft and Walton, working at the Cavendish Laboratory, Cambridge, England (see last year's Annual Report). The results obtained in our experiments on lithium and boron were in agreement with newer results reported by Cockcroft and Walton while the measurements here were in progress. It was found that there was a large number of disintegration-particles from boron of short range (less than 28

mm.) with a much smaller number of particles of somewhat longer range. For lithium there are apparently two groups of about equal number, the shorter range being just under 2 cm., with a total yield of about one-twentieth that of boron.

Calculations on the basis of the Gamow-Gurney-Condon wave-mechanics theory have shown that, with the available voltage and current, using He^+ -ions to bombard a beryllium target, the emission of neutrons might be expected with an intensity just on the limit of detection of the linear amplifier; this limit had been determined by the neutron-emission of a beryllium target bombarded by the alpha-particles from a polonium-source of known strength. Since it is of primary importance to determine the limits within which this theory is valid, tests were made for such "artificially" produced neutrons, using the original tube and also using the new tube constructed for larger currents, with negative and hence inconclusive results as far as the predictions by Gamow's formula are concerned. However, other data indicate the validity of the wave-mechanics theory, and on this basis it is expected that with the higher voltages of the 2-meter generator a neutron-source stronger than almost any possible radioactive neutron-source will be obtainable.

The original publication of Cockroft and Walton reported that disintegration-alpha-particles were also observed in considerable numbers when targets of medium and heavy elements were bombarded. This result, if substantiated, would have been an exceedingly strong contradiction of the wave-mechanics theory, which correctly predicted the disintegration of the lighter elements by protons and which is at present the only theory in existence for predicting the behavior of particles within or approaching the nucleus. It was, therefore, decided to repeat these observations, and aluminum, nickel and silver were selected as representative of the elements of medium atomic number for which they observed disintegrations. Photographically recording the disintegration-particles by means of the linear amplifier and using a shutter ahead of the target to obtain the residual counts—thus eliminating any spurious effects due to contamination or electrical disturbances—two targets each of aluminum and silver and one of nickel were bombarded by 500 to 600 kilovolt protons. Except for the use of higher voltages, which should give a larger and not a smaller number of disintegrations, the apparatus duplicated in all essentials that used by Cockroft and Walton. The disintegration-yield from a boron-target in the same apparatus eliminated any dependence on measurements of target-currents or measurements of the percentage of protons in the ion-beam. The disintegrations observed with the targets of aluminum, nickel and silver were less than one per cent of those reported by Cockroft and Walton at 300 kilovolts and would be accounted for by the presence of boron-contamination in or on these targets to the extent of one part in 33,000, 9000, and 100,000, respectively. Contamination by boron to this extent is readily to be expected unless extreme precautions are taken. While these experiments were in progress, the Cavendish Laboratory announced on the basis of later work at 200 kilovolts that the disintegrations reported for lead and uranium were probably due to boron-contamination. It thus appears that there is no real basis as yet for doubting the validity of the wave-mechanics theory of

nuclear penetration, except possibly for the lightest elements with very high-voltage protons, when the probability of penetration approaches unity. The installation of the 2-meter generator should make possible the extension of a variety of disintegration-experiments, including the use of the hydrogen-isotope of mass two (H^2) as the projectile, to a group of elements of medium atomic number which is nearly inaccessible at voltages of 600 kilovolts, since the probability of penetration of such nuclei rises exponentially with voltage in this region.

Experiments using radioactive sources—As a check on observations using the high-voltage technique, and also as an independent tool of great importance in certain specific problems, considerable effort has been spent during the past two years on the application of radioactive sources, particularly polonium,¹ to studies in nuclear physics. During this year, in addition to the development of the technique of preparing very pure sources, two particular experimental applications were undertaken. Observations were made using the linear amplifier, the FP-54, and the Wilson cloud-chamber, which verified the essential features of the experiments which led Chadwick, several months previously, to announce the discovery of the neutron. Since the polonium-source available here has less than one-tenth the strength of that used by Chadwick, an extension of these experiments was not attempted.

The question as to the existence of "resonance-disintegration," where a nucleus is penetrated by an alpha-particle because of a resonance-phenomenon rather than by "brute force," is of fundamental importance to the wave-mechanics theory. Experimental evidence for the phenomenon was put forward by Pose in 1930, followed by contradiction, confirmation and contradiction by workers in other prominent radioactivity laboratories, and by a recent extension of the work in Pose's laboratory which completely checks his original conclusions. Experiments were undertaken here using the FP-54 as the detecting instrument in order to obtain an entirely independent series of observations on this important problem. The experiments have not been completed, but the observations have given a result which checks Pose's disintegration-yield on an absolute basis (disintegrations of aluminum-nuclei per 10^8 alpha-particles), which had been claimed to be too large by a factor of about 10. Consideration of certain of the experiments which "contradicted" those of Pose showed that the geometrical relations of source, target and detector would completely "wash out" the effect which it was desired to observe. Other features of the results were in agreement with Pose's observations, and although measurements of the sharpness of resonance have not yet been made (due to the difficulty of obtaining a strong polonium-source sufficiently free from radium E), it is believed that there

¹The program of nuclear disintegration studies, using radioactive sources, was made possible only by the generous cooperating of the following individuals and institutions, for which grateful acknowledgment is made: Dr. C. F. Burnham and Dr. F. West, Kelly Hospital, Baltimore, Maryland; Dr. G. Failla, Memorial Hospital, New York, New York; Dr. J. L. Weatherwax, Philadelphia General Hospital, Philadelphia, Pennsylvania; Dr. M. C. Reinhard, State Institute for the Study of Malignant Disease, Buffalo, New York; Dr. Carl E. Nurnberger, University Hospitals, Minneapolis, Minnesota; Dr. Otto Glasser, Cleveland Clinic Foundation, Cleveland, Ohio; and Dr. Roscoe W. Teahan, Jeanes Hospital, Philadelphia, Pennsylvania. The facilities of the radium laboratory of the United States Bureau of Standards were generously extended for the preparation of these radioactive sources.

can be little doubt as to the existence of the phenomenon of nuclear penetration by resonance.

Development of instruments—A technique which is fundamental in almost all branches of research is that of the measurement of very small currents. Studies in the Department's laboratory during the past two years of the fluctuations which limit the useful sensitivity of the FP-54 vacuum-tube have led to a clear demonstration that these fluctuations (root mean square ± 600 electrons) are no larger than the fluctuations which must arise from the thermal agitation of electric charges in materials at room-temperature. This instrument thus attains its theoretical limit of sensitivity. The Hoffmann duant-electrometer has been shown in other laboratories to reach its approximate theoretical limit also (± 1000 electrons). The convenience of the FP-54 is a valuable advantage, and this work has indicated the possible changes by which a further improvement of the instrument may be achieved. This study of the limiting factors in the measurement of extremely small currents (measurement of 7×10^{-18} ampere is made to 5 per cent in several minutes or less) and of the application of the FP-54 to the counting of high-speed protons from disintegrating atomic nuclei has been one of the most important of the projects carried out during the year. However, the linear amplifier for counting protons and alpha-particles mentioned in last year's report also has been further studied, resulting in a reduction of the "noise-level" which is its limiting characteristic. Single high-speed protons can be detected with certainty (above the maximum "noise"-peaks), using an ionization-chamber only a few millimeters deep and in the presence of the mechanical and electrical disturbances produced by the electrostatic generators.

A new design of Wilson cloud-chamber, which has advantages of great practical importance, was built, tested, and put into use during this year. A flexible metal bellows (sylphon) replaces the piston and cylinder of the usual chamber, eliminating leaks, allowing any orientation and retaining the gas-composition initially introduced into the chamber.

THEORETICAL

G. Breit of the faculty of New York University as research associate of the Institution continued his theoretical studies at the University. The following paragraphs briefly summarize features of his studies and related experimental work.

The isotope shift of spectrum lines—The relative positions of lines due to different isotopes of the same element have been correlated with possible and reasonable differences in the nuclear radii of these isotopes. The theory has been applied specifically to mercury, thallium, lead. All of the available data for these elements are reasonably explained on the supposition that the nuclear radius is greater for the heavier isotopes. The change in nuclear radius thus obtained is approximately of the magnitude which would be expected if the protons and neutrons were packed inside the nucleus with the same density.

The experimental material on the lighter elements neon, zinc, copper, indicates the presence of other effects such as that of the mass of the nucleus, and it appears possible that in the case of zinc the heavier isotopes have smaller radii. These points require further investigation.

The nature of the effective nuclear magnetic moments—Until recently there have been grave difficulties in explaining the hyperfine structure of spectrum lines as due to a magnetic moment of the atomic nucleus. In work done jointly with L. A. Wills, it became apparent that these difficulties were due to an insufficient understanding of the theory of ordinary spectra and it has been shown that they may be reasonably explained by taking into account perturbations between different electronic configurations. This conclusion is in agreement with the work of Fermi and Segré, who arrived at it by different methods. The nuclei of most elements exhibiting spin may be thus reasonably pictured as being small magnets. (Calculations on the hyperfine structure of lithium carried out by N. M. Gray at this laboratory show an excellent agreement of the observed patterns with a spin of $3/2$ and eliminate other reasonable possibilities for the spin.)

The effect of hyperfine structure on the polarization of resonance-radiation—Formulæ have been developed which allow the calculation of the polarization of resonance-radiation for lines having hyperfine structure in the presence of externally applied magnetic fields. These have been applied by Mitchell to the data on mercury and cadmium and good agreement with experiment was found by him. Formulæ have also been derived for cases in which the hyperfine structure-splittings of the upper levels are comparable with the natural breadth of the line. These have been applied by Ellett to the resonance-radiation of sodium and with their aid the experimental values of the polarization in zero-field were found to agree with a nuclear spin of $3/2$.

Related experimental work—Granath and Van Atta at the laboratory of the University have made a determination of the nuclear spin of sodium by means of relative intensity-measurements of the hyperfine components of the *D*-lines. The measurements were made by practically a null-method, the intensity of the weaker component of the stronger *D*-line being compared with that of the stronger component of the weaker *D*-line. The result is $3/2$ for the nuclear spin, in agreement with the determination of Rabi and Cohen and of Ellett and Heydenburg. Quite different methods have been employed in the three investigations and the result may be considered as absolutely certain.

The magnetic interaction of a valence electron with closed shells—Jointly with Dr. Johnson the theory of doublet splittings has been reexamined from the point of view of the exact treatment by means of Schrodinger's equation. New exchange-effects have been found. Numerical calculations showed these to be too small to explain the anomaly of the inversion of alkali doublets. The only remaining explanation consists in perturbations by other electronic configurations.

TERRESTRIAL ELECTRICITY

The personnel of the Section of Experimental Work in Terrestrial Electricity consisted of Gish (Chief of Section), Rooney, Sherman and temporary assistant-computers Nutting and Wiener. Wait and Torreson, besides compiling atmospheric-electric data as reported elsewhere, and Forbush and McNish also carried out experimental and theoretical investigations in terrestrial electricity.

Polar-Year program in terrestrial electricity—The program in terrestrial electricity planned for the International Polar Year Station College-Fairbanks is perhaps the most extensive ever undertaken at a polar station. It includes continuous registrations of northward and eastward earth-current components, of air-potentials and of both positive and negative air-conductivity and visual observations of density of small ions and of Aitken nuclei together with certain meteorological observations. Continuous air-potential registrations were indicated also for a large portion of the time at a hut so situated that with suitable equipment (stretched-wire method) the recorded values are unaffected by the contour of the land or by buildings, etc. The latter are for the purpose of converting those registered more steadily at the observatory-station proper. As elsewhere reported, the entire program is being successfully realized despite the polar conditions, except the schedule for the Aitken counter which failed during the colder weather.

At this station the strength of the earth-currents often varied rapidly. These periods of disturbance appear to be closely associated with the occurrence of polar lights. The greatest activity in both generally occur shortly after midnight. Despite the considerable disturbance in the earth-currents, the variation during the day is shown, by Rooney's compilations of the average hourly values for the month, to be consistent from month to month. Here as at Watheroo, Huancayo, Ebro, and some other stations, both the rapid variations and the diurnal variations are much restricted in direction, the changes being analogous to a shuttle motion.

Preliminary inspection of the atmospheric-electric data from College-Fairbanks has revealed few unusual features. Perhaps the most conspicuous was the small number of days on which the air-potential was negative at any instant. The conductivity appears to be a bit greater and the potential gradient somewhat less than at many land stations. The diurnal variation in the air-potentials as charted by Sherman shows three maxima which apparently coincide in time on a universal basis with apparently corresponding points on the graph for oceanic data. The three "maxima" on the ocean graphs were early noted as possibly significant but at that time the data did not establish a high probability of this. However, they now appear in a sufficient number of independent sub-groups to indicate that they are of real significance; hence the comparison here made with the College results seems justified. The secondary maxima are more pronounced and the rise to the principal maximum is steeper in the College data than in those obtained on the *Carnegie* at sea or by the *Maud* Expedition in north polar regions. This suggests the presence of some local influences which will be a subject of further study when the observational program is completed. (For other details of Polar-Year cooperation, see section of this report on observatory-operations.)

Atmospheric electricity—The reduction of atmospheric-electric data for the Tucson Observatory was completed through 1931 by Gish with the assistance of Nutting and Wiener, and specific instrumental problems were studied in attempts to determine whether a better system of control is required and where necessary to ascertain methods of improving instruments and procedure. In one such study, Gish found that the part which turbulent air-flow

plays in the Ebert type of ion-counters and in the Gerdien type conductivity-apparatuses has apparently been underestimated. As a result of this study it is concluded that the factor, which in the past has been termed "The capacity of the part of the insulated system exposed to the air-current," appears to be affected in the actual apparatuses by turbulent flow. Hence and because the expression becomes meaningless in some cases—such as the Swann modification of the Ebert ion-counter—he suggests that the significance of the factor would be better expressed by the term "conductance-factor." It is concluded also that attempts to ascertain the limiting mobilities, or the working potential or rate of air-flow corresponding to a given limiting mobility of any ion-counter or conductivity-apparatus, by calculation according to the usual formulæ are likely to yield untrustworthy results. The part which eddy-diffusion in the atmosphere plays in affecting the electrical equilibrium was also investigated by Gish. One conclusion is that eddy-diffusion makes an appreciable contribution to the apparent rate of formation of ions and that this rate may be appreciably different for the small ions of one sign than for those of the other. It is also concluded that a similar contribution is probably made in the case of large ions and Aitken nuclei under circumstances which may frequently occur in the atmosphere.

Atmospheric pollution and its relation to atmospheric ionization—The investigations by Wait and Torreson on the relation of atmospheric pollution and ionization were continued. The large-ion counter functioned satisfactorily and continuously and no serious difficulties were encountered in its operation. The chief difficulty was leak, presumably across small particles adhering to the walls of the air-flow tubes and causing partial or intermittent leaks. Dismantling the air-flow system and cleaning it thoroughly by rubbing the surfaces exposed to the air-flow with a cloth, or chamois, or with fine emery paper, has been found to remedy this.

Measurements of small-ion content with an apparatus constructed by Wait and McNish were initiated late in June 1932, but instrumental difficulties prevented successful recording until the end of September. Insulation-leak and bad fibers were chiefly responsible for the difficulties. In January 1933, it was found that the small-ion counter was recording not only small ions but conductivity as well, due to intermediate and large ions, and that the contribution from conductivity was a large part of the total effect recorded. Tests to separate the various effects could not be made until May, when a scavenging condenser was placed at the intake of the ion-counting apparatus by which small ions were removed before entering the ion-counters, thus leaving the effect of the intermediate ions, chiefly, to be recorded by the small-ion counter, the large-ion effect on that counter being negligible.

The large-ion data obtained April to September 1932 were compiled and monthly mean diurnal-variation curves drawn. For comparison with the large-ion data, positive conductivity-records obtained in April, May and June, on the laboratory grounds with the apparatus subsequently sent to Alaska, were compiled and diurnal-variation curves drawn. Comparison of the records of large ions and of conductivity shows the reciprocal character of the two elements. This reciprocal character is displayed even better by graphs of positive large and small ions obtained January 1933 with the De-

partment's ion-counting apparatus. (Details of the work on large and small ions are given in the section of this Report giving brief progress-reports.)

Earth-currents—The observations made by Forbush using electrodes displaced vertically in a dry well at the Huancayo Magnetic Observatory were analyzed and described by him in a published paper. The subject of apparent vertical earth-currents was considered further by Gish, who prepared several notes on this matter.

Miscellaneous—Conferences were held by Gish in Kansas and Nebraska with members of the Physics Department of Kansas State College at Manhattan (where investigations in atmospheric electricity have been recently undertaken), with Professor Dinsmore Alter of University of Kansas at Lawrence regarding his methods of investigating cycles of interest in many branches of geophysics, and with Professor J. C. Jensen of Nebraska Wesleyan University at Lincoln, who from a number of years of investigations of thunder-storms has obtained notable results in this aspect of atmospheric electricity.

Several conferences were held with Dr. G. C. Southworth who is in charge of the earth-current work being done by the American Telephone and Telegraph Company. Collaboration was given Benjamin E. Jones of the United States Geological Survey regarding technical details of earth-resistivity measurements in his expected use of such measurements in Washington and Oregon to investigate prospective dam sites.

FIELD-WORK AND REDUCTIONS

LAND MAGNETIC SURVEY

The work of the Section of Land Magnetic Survey during the last half of the year was handicapped by the death on December 26, 1932, of its Chief, Harlan W. Fisk. Following Fisk's death, Green, his first assistant, has been Acting Chief of the Section. Wallis and Duvall were on duty in the Section throughout the report-year. Hanson and Mansfield also assisted in the Section's work while not on field duty.

The study of secular changes in the Earth's magnetic elements continues to be of paramount importance and the efforts of the Section have, in large part, been directed along this line during the year. On account of economic conditions, curtailment of field-operations has been necessary, but the accumulation of data was continued through limited expeditions sent from the Department and through cooperative work with other organizations being done in South Africa, in British East Africa and in China.

Hanson completed the expedition upon which he was engaged at the beginning of the year. Ledig left the Huancayo Magnetic Observatory early in December for work in the southern part of South America, covering sections not included in the expeditions of Green during 1931-32 and of Hanson undertaken at the same time and extending well into the present year.

Derivation of secular variation in declination in the Pacific at track-intersections of the *Galilee* and *Carnegie* has been continued after the method devised by Fisk and involving a limited use of the least-square principle. A paper describing the process in detail was prepared and presented by Green at the Fifth Pacific Science Congress which he attended as a representative of the Carnegie Institution of Washington.

The Department is lending its best efforts to forwarding the plan of the International Association of Terrestrial Magnetism and Electricity for increasing the number of magnetic observatories, especially in the southern hemisphere, and particularly for establishing a network of repeat-stations covering the entire world which, when realized, will supply the necessary data for comprehensive continuing research in the problems of secular variation.

A preliminary examination of the data collected during the year emphasizes Fisk's conclusion that the phenomenon of secular variation is regional in character and that the acceleration in the annual changes of the elements is far from constant. Repeat-observations like those made in South America by the Department in the past two years are greatly needed in other parts of the world and particularly in Africa to supply material to complete world-wide studies of isoporic changes during the present epoch.

FIELD-OPERATIONS AND COOPERATIVE SURVEYS

Field-operations during July 1932 to June 1933 are briefly detailed in the following paragraphs for each of the continents so far as reports from observers and cooperating institutions have been received.

Africa—The cooperative work with the University of Cape Town has been continued. Magnetometer and inductor 17 were shipped from Washington in July 1932 and are being used for base-line control at the temporary magnetic observatory of the International Polar Year at Cape Town, two complete la Cour magnetographs and appurtenances having been loaned to the University by the Polar Year Commission.

The arrangement with Director A. Walter of the British East Africa Meteorological Service for cooperative magnetic work in that region has been continued, though because of curtailment of activities in the Meteorological Service due to the economic situation only two additional stations (Kampala and Nakaru) were occupied during the year. With the improvement of economic conditions, observations will be made at the remainder of the 20 stations in British East Africa as originally planned.

Asia—Cooperative magnetic work under the direction of F. C. Brown, formerly an observer on the staff of the Department, now connected with the American Church Mission at Hankow, assisted by Dr. C. T. Kwei of the Department of Physics of Central China College at Wuchang, has been continued throughout the year. Repeat-observations were obtained by Brown at the following stations: Peiping, 1907; Peiping, 1916; Peiping, *C*; Kalgan, 1907; Kalgan, *B*; Tienchen; Shihkiachwang, *A*; and Shihkiachwang, *B*. Kwei observed at the following stations: Chengchow, *A*; Chengchow, *B*; Shenchow, *A*; Shenchow, *B*; Sian, *A*; Sian, *B*; Changte, *A*; Changte, *B*; Taiyuanfu; and Tienchen. During two weeks' leave from his College in February, Brown made intercomparison observations at Zose, comparing C. I. W. magnetometer and inductor 13 simultaneously with Smith magnetometer L35416 at Zose and with Elliott magnetometer 49 at Lukiapang. Elliott magnetometer 49 was then brought to Zose and further simultaneous observations were secured there. Dr. C. L. Ting of the National Academy of Sciences at Peiping had brought from Peiping the Academy's new Smith magnetometer L44308, but because of trouble which developed with the suspension-tube of this instrument intercomparisons could not be obtained. C. I. W. inductor 13 and Schulze inductor 42 of the Zose Observatory were also compared. Beginning November 1, 1932, Brown and Kwei, alternating

every three weeks, have made absolute and diurnal-variation observations at Wuchang. The absolute determinations as at a field-station were obtained every other week, and diurnal-variation series for declination and horizontal intensity with a like series for inclination were secured on the alternate weeks intervening. Kwei left for Chungking June 29, 1933, and planned to work thence through Chengtu, Kiating, Omeishan, Suifu and Luchow, reoccupying all these stations. Unfortunately the disturbed conditions in this region interfered with the plan after the completion of the work at Chungking, and he therefore proceeded down the river from Chungking, observing at C. I. W. repeat-stations occupied by C. K. Edmunds in previous years.

Australia—No field-work for secular variation other than that effected through the observations at the Watheroo Magnetic Observatory has been undertaken in Australia.

North America—Comparisons on the Department's standard instruments to control the constants and corrections of instruments used in the field have been made as usual in the Standardizing Magnetic Observatory at Washington. These observations have been made for each instrument both before and after each trip in the field. Magnetometer and inductor 17 were standardized and sent to the University of Cape Town; magnetometer-inductor 26, which had been returned by Green after his trip in South America, was standardized and was sent to Ledig at Huancayo for further work in South America; magnetometer and inductor 16, returned by Hanson in February 1933, were standardized.

South America—Hanson, completing his expedition begun in 1931 in the West Indies, secured much-needed observations in Brazil, Peru, Ecuador and Colombia before returning to Washington in February. His observations, July 1932 to February 1933, covered at 34 stations 23 localities—Brazil 2, Peru 13, Ecuador 2 and Colombia 6. In Peru, intercomparisons of the field-instruments with those of the Huancayo Magnetic Observatory were made by simultaneous observations with exchange of stations. Hanson lost no opportunity to emphasize the importance of the work being done by the Department in South America as well as other parts of the world. In Ecuador he contacted with officers of the Army much interested in magnetic work, who prevailed upon him to give them preliminary instructions in the use of instruments and in the methods of observing and computing, anticipating a later magnetic survey of their country by the Government of Ecuador.

Early in December, P. G. Ledig, after transferring charge of the Huancayo Magnetic Observatory to Cairns, proceeded southward from Lima on an expedition designed to round out the network of recent observations at secular-variation stations in South America embraced by the expeditions of Green completed in June 1932 and that of Hanson extending to February 1933. Arrangements had been made with Dr. Arthur H. Compton of the University of Chicago in the latter's geographic survey of cosmic-rays sponsored by the Carnegie Institution of Washington through a special grant from the Carnegie Corporation whereby Ledig was to make observations also on cosmic radiation at various sea-level points. On this expedition, observations were secured at Mollendo in Peru, Santiago, Puerto Montt and Magallanes (Punta Arenas) in Chile, and in Santa Cruz, Puerto Deseado, Colonia las Heras, Puerto Madryn and Dolavon in Argentina. Of these, three were Class I stations, two were Class II and four were Class III. Cosmic-ray observations were made at Lima and Mollendo in Peru, Valparaiso, Sewell, Puerto Montt, and Magallanes (2) in Chile, and Puerto Deseado in Argentina.

At Santiago (Chile), Ledig renewed contacts made by Green with Director J. Valensuela and other officials of the Meteorological Service of Chile and was able to give them some assistance toward organizing the work for the Polar Year station at Magallanes. Upon arrival at Magallanes, March 9, he assisted in various matters pertaining to the operation of the variometers and through a small allotment from the Department constructed a non-magnetic shelter for necessary control-observations with the absolute instruments. It was possible also for him to further assist Sr. U. Matassi, the Observer-in-Charge, by instruction in the technique of handling the magnetometer and earth-inductor. Later on, an intercomparison of these instruments with C.I.W. magnetometer-inductor 26 was effected. From these data the relative constants of the absolute instruments at Magallanes were determined. Leaving Magallanes May 13, he arrived in Santa Cruz May 15, and he reached Puerto Deseado May 25, whence a short trip was made inland to Colonia las Heras. From Puerto Madryn, where he arrived June 16, another short trip inland was made to Dolavon. At the close of the year he was in Buenos Aires. Here Ledig will renew contacts with officials of the Meteorological Service of Argentina, with which Service this Department has for many years maintained close cooperation. At Montevideo, Uruguay, he was to confer with the Hydrographic Office of the Navy and with officials of the Naval School at the latter's request with reference to the C.I.W. type of combined magnetometer and earth-inductor and the magnetic survey of Uruguay. After conferring at Rio de Janeiro with Director Sodre da Gama of the National Observatory, Chief of Magnetic Section Lemos, and officers of the Meteorological Service of Brazil, he was to occupy the three repeat-stations Catalão, Bella Vista and Goyaz. Cosmic-ray observations at Santos will complete the expedition.

Secular-variation data were also effected through the regular observations made at the Huancayo Magnetic Observatory during the year for the control of the photographically registering apparatus.

OBSERVATORY-WORK

Johnston has continued as Chief of the Section of Observatory-Work, having the assistance of McNish, Forbush and Miss Balsam, and part-time assistance of Ennis, Wait, Torreson, Scott, Hendrix and Miss Ennis. The members of the staff engaged in the field are mentioned in the reports for the observatories.

The instrumental installations to extend the geophysical activities of the Department at its two observatories referred to in last year's report were installed and are now in regular operation. Two rapid-run magnetographs of the la Cour design loaned by the International Polar Year Commission were installed, one at Watheroo and one at Huancayo as indicated below. The third inductometer for making high-speed records of minute changes in magnetic vertical-intensity after the design of A. Crichton Mitchell was shipped to the Huancayo Observatory and will be placed in operation there during the coming year.

The equipment for measuring the virtual heights of the electrical conducting layers in the upper atmosphere as designed and constructed in the instrument-shop, utilizing the echo-method developed by Breit and Tuve with improvements designed by the United States Bureau of Standards, was completed. The balance of the equipment for the Huancayo Observatory was forwarded and installed so that regular observations of the ionosphere

began in June 1933. The whole equipment with motor-generator and appurtenances was delivered at the Watheroo Observatory and, after completion of the necessary radio laboratory, was being installed at the end of the report-year.

Assistance was given the Division of Terrestrial Magnetism and Seismology of the United States Coast and Geodetic Survey in the design of a comparison and test building and for the rebuilding of the office and absolute observatories at the Cheltenham Magnetic Observatory. This is in anticipation of more intensive cooperation between the Survey and the Department in laboratory and experimental work relating to terrestrial magnetism and electricity. The completion of this building at Cheltenham will make it possible in future for the Department to maintain its standard instruments at that Observatory for intercomparison of standards. Plans for the installation of earth-current and, later, atmospheric-electric equipment at the Cheltenham Observatory by the Department were initiated also.

OBSERVATORY-OPERATIONS

The summaries below briefly review the operations during the report-year at observatories of the Department and at those observatories with which the Department cooperated in various phases.

Watheroo Magnetic Observatory, Western Australia—The Watheroo Magnetic Observatory is situated in latitude $30^{\circ} 19' 1''$ south and longitude $115^{\circ} 52' 6''$ east of Greenwich, 244 meters (800 feet) above sea-level.

The preliminary mean values of the magnetic elements for all days of the year 1932 as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: Declination $-3^{\circ} 58' 5''$; horizontal intensity 0.24652 C.G.S. unit; vertical intensity -0.51267 C.G.S. unit; and inclination $-64^{\circ} 19' 2''$. The preliminary values of the annual changes in the magnetic elements for the period 1931.5 to 1932.5 are $+4.7$ in declination, $+6$ gammas in horizontal intensity, -52 gammas in vertical intensity and -1.2 in inclination.

During August 1932 a rapid-running magnetograph, after the design of la Cour, was received from the International Polar Year Commission. After some necessary modifications had been made to the existing piers in the magnetograph-room, the la Cour variometers and recorder were installed and magnetograms have been obtained regularly since the end of November 1932. A switchboard to control the currents in the Helmholtz-Gauguin coils during scale-value determinations was installed in the Office. Some improvements were made in the recording-apparatus of this equipment and the records are very satisfactory.

Earth potentials, over the system described in previous reports, have been continuously recorded. Portions of the electrode-connectors adjacent to the atmospheric-electric observatory, which were formerly subterranean and had given evidence of defective insulation, have been replaced by aerial connectors. During the dry season, the potentials from electrode N_x exceed the limits of registration and steps are being taken to replace this electrode by another in a more suitable location. The Leeds and Northrup multiple-point recorder has been overhauled and the wearing parts renewed.

Records of air-potentials have been obtained throughout the year. The usual difficulties due to defective insulation from spider-webs during certain seasons were encountered and these, together with abnormal potentials

recorded during bush-fires, rendered many otherwise complete "zero" days of doubtful value; such days are, of course, excluded in the consideration of the monthly means and diurnal variations. Standardization observations were obtained at approximately monthly intervals as before. The mean of the series for 1932 gives a reduction-factor of 1.11 as compared with the mean value of 1.12 for 1932 and 1.11 for 1930. The preliminary mean value of the potential gradient for the year 1932 is 84.1 volts per meter.

Work with the potential-gradient field-recorder during this report-year was confined to a reoccupation of the Moora station during December 1932. The use of the underground recording-chamber for reduction-factor investigations has been delayed owing to pressure of other work.

Positive and negative air-conductivities have been recorded as in previous years, the usual weekly calibrations and other control observations being made. Incompleteness of the records during January, February and March is attributable to the smoke from bush-fires. The preliminary mean value of the positive air-conductivity for the year 1932 is 1.92×10^{-4} E.S.U. and for the negative conductivity 1.68×10^{-4} E.S.U.

Installation of the remodeled atmospherics-recorder on loan from the Australian Radio Research Board of the Council for Scientific and Industrial Research has continued as time permitted. Regular recording began at the end of May 1933; some minor adjustments and improvements remain to be made.

The Mitchell vertical-intensity inductometer has been installed on specially constructed piers in the atmospheric-electric observatory and continuous records have been obtained since early October 1932. The horizontal loop for use with this instrument around the boundary-fence, enclosing an area of 180 acres and which was mounted during the previous report-year using lead-covered wire which had previously been used as subterranean earth-current connectors, was found to have defective insulation because of corrosion of the lead sheathing and was replaced entirely by new lead-covered wire, mounted on button insulators.

The complete equipment to be used for the determination of the heights of the ionized layers of the upper atmosphere has been received and the construction of the radio laboratory and power-house was nearing completion at the end of the report-year. The usual radio schedules were maintained and official messages regularly transmitted and received.

The usual meteorological observations were made daily and the self-recording meteorological instruments were kept in continuous operation. A Hellman-Fuess 8-inch pluviometer, on loan from the Australian Weather Bureau, was installed in July 1932. The Aitken dust-counter, also on loan from the Australian Weather Bureau, was repaired and improved in construction and is now in regular use.

All computations and reductions have been maintained current. Various memoranda on instrumental equipment and procedure have been prepared by members of the staff. Two papers for presentation to the Fifth Pacific Science Congress at Vancouver in June 1933 were prepared by Parkinson. Meteorological data have been supplied to the Australian Commonwealth Weather Bureau and abstracts of atmospheric-electric observational data have been supplied to the Commonwealth Solar Observatory at Mount Stromlo as in previous years.

Constructional, improvement and repair work effected during the year, other than that necessitated by installation of new equipment as outlined above, includes the following: The power- and light-lines have been rewired and rearranged; buildings have been repainted; the roofs of the variation

and absolute observatories have been recovered with felt roofing; eroded sand around the variation observatory has been replaced, leveled, and covered with clayey gravel; a waste-water disposal system has been installed at the observers' quarters; a bathroom has been built in the attic of the observers' quarters; the ceilings of the verandahs of the observers' and auxiliary quarters have been lined with asbestos sheeting; a garage for the new Ford light delivery truck has been built; a room for storing electrical and mechanical parts has been built; a room in the auxiliary quarters has been fitted up as a mixing-room for photographic solutions and this room also contains a built-in cabinet with reel for drying the Mitchell traces; portions of the road to Watheroo have been straightened and re-graveled.

Parkinson was observer-in-charge throughout the year. Observer Wood continued as chief assistant. Curedale and Culmsee acted as junior observers, the former also operating the radio equipment. Hogan was appointed on a temporary basis as junior observer on January 19, 1933. Caswell continued as electrician and mechanic throughout the year. The successful accomplishment of the heavy program of routine work as well as the installation and adjustment of new equipment throughout the year is a tribute to the industry and efficiency of all the assisting staff.

Visitors to the Observatory during this report-year have included the following: Professor A. D. Ross of the University of Western Australia; Mr. A. Cameron, Government Surveyor of the Malay States; the Hon. J. Scaddan, Minister for Railways; the Rev. Archdeacon C. L. Riley of Perth; Col. E. H. Nicholson; His Grace the Lord Archbishop of Perth (Dr. le Fanu); and Mr. A. Knapp, F.R.P.S. of Perth.

Acknowledgment of assistance rendered to the Observatory by outside persons and organizations is gratefully made to the following: The Commonwealth Department of Trade and Customs for the entry of equipment and supplies free of import duty; the Radio Research Board of the Council for Scientific and Industrial Research for cooperation and assistance in the radio program; H. C. Cooper of Glenelg, South Australia, for the relaying of official radio messages to and from Washington; Senator Sir Walter Kingsmill and Professor A. D. Ross for their continued lively interest and valuable assistance in the Observatory's work.

Huancayo Magnetic Observatory, Peru—The Huancayo Magnetic Observatory is situated in latitude $12^{\circ} 02'7''$ south and longitude $75^{\circ} 20'4''$ west of Greenwich, in the central valley of the Peruvian Cordillera at an elevation of 3350 meters (11,000 feet) above sea-level. Huancayo, the terminus of the Ferrocarril Central del Perú, is 15 kilometers distant by road from the Observatory.

The preliminary values based on the magnetograms for all days during the year 1932 are as follows, reference being made to the north-seeking end of the needle, east declination and north inclination being reckoned positive: $+7^{\circ} 25'6''$ in declination; 0.29617 C. G. S. unit in horizontal intensity; $+0.01021$ C. G. S. unit in vertical intensity; $+1^{\circ} 58'4''$ in inclination. The preliminary values of the annual changes for the period 1931.5 to 1932.5 are $-5'2''$ in declination, -5 gammas in horizontal intensity, $+70$ gammas in vertical intensity, and $+8'1''$ in inclination.

The preliminary mean value of the potential gradient at the Observatory for the calendar year 1932 was 49 volts per meter, as based on 71 days of zero electric character. Of those days during which no negative potential was recorded, 55 occurred during the dry season from May to August and 16 during the remaining 8 months of the year in which rain falls almost

daily. Standardization observations were obtained on 6 days, giving a mean reduction-factor of 1.14, as compared with the value 1.08 obtained during the preceding year.

The mean value for the calendar year 1932 of the positive conductivity of the atmosphere for 71 zero-days was 4.35×10^{-4} E.S.U. and the mean value of the negative conductivity was 4.36×10^{-4} E.S.U. For purposes of comparison with zero-days, 49 days on which the conductivity was not extremely disturbed were selected during the rainy season. The positive conductivity in the selected days was 4.42×10^{-4} E.S.U. and the negative conductivity was 4.32×10^{-4} E.S.U.

Earth-current potentials were measured as in previous years, with a loss of approximately 20 days owing to thunder-storms. At the end of the report-year, a panel and switching-system was received, the purpose of which was to facilitate operation and to lessen materially difficulties due to electrical storms. No changes were made in the electrode- or recorder-arrangements.

Meteorological observations and tabulations were continued as usual.

Spectroheliometer observations were made regularly from August 7, 1932, when conditions allowed. Due, however, to persistent cloudy weather and to difficulties with the instrument, the results obtained were not entirely satisfactory.

The seismological station, including the two Wenner horizontal-component seismometers and a Benioff vertical-component seismometer (received August 10), was completed, and records were obtained beginning August 19, 1932. The seismograms, together with the preliminary determinations of the numerous quakes, were transmitted to the United States Coast and Geodetic Survey twice monthly through the Washington office.

The apparatus for the study of the heights of the upper ionized regions of the atmosphere, as developed at Washington by the Department in conjunction with the United States Bureau of Standards and constructed in the Department's instrument-shop, was installed and put into operation early in May 1933. The program as outlined for the International Polar Year was adhered to, and other observations were carried out. The equipment utilizes the "echo" method as originally developed by Breit and Tuve at the Department in that radio-frequency pulses at the rate of 90 per second are transmitted, and the time-delay between the echo or echoes and the ground-pulse is measured directly in kilometers by means of a synchronous oscillograph-unit. The location at Huancayo is unique, being practically on the magnetic equator, and it is anticipated that the results obtained will furnish valuable information concerning radio-transmission phenomena as well as data concerning the upper atmosphere.

The Mitchell loop recorder for registering rapid changes in the vertical component of the Earth's magnetic field was received, but the installation of the apparatus was postponed pending the arrival of the cable for the loop and the selection of a suitable location for the recorder itself.

In connection with the Polar Year program, a la Cour rapid-running magnetograph was installed. Although magnetograms were obtained beginning January 1, it was some time before the final adjustments of the apparatus were made and entirely satisfactory records were obtained.

The Observatory staff was pleased to be of assistance to Professor A. H. Compton in carrying out the Peruvian portion of his geographic study of the penetrating-radiation. During the period from July 1 to 6, 1932, Cairns assisted with the observations that were being made at five stations on the

Central Railroad at elevations varying from 500 feet at Lima to 16,960 feet in the Galera Tunnel. Ledig assisted in making diurnal variations at Huaytapallacu Pass (15,000 feet) from July 8-14, and later accompanied Professor Compton to Arequipa to aid with observations at elevations ranging from sea-level at Mollendo to the summit of El Misti (over 19,000 feet).

Continuous photographic records of the ionization due to penetrating-radiation were made by Cairns. These records, extending over a period of several months, indicated the potential-difference across a fixed high-resistance through which the ionization-current was flowing. Information was obtained on the diurnal variation, frequency and magnitude of "bursts," and concerning the effects of thunder-storms. Preparations were being made at the end of the report-year for further studies of the penetrating-radiation both at the Observatory and in the field. Apparatus was under construction at the Observatory for use in the high country northeast of Huancayo, and additional equipment was en route June 30, 1932, from Washington. Plans were made to have J. C. Street and H. R. Mimno of the Jefferson Physical Laboratory of Harvard University spend two months beginning July 3, 1933, at the Observatory and in Peru securing observations relating to special researches pertaining to penetrating-radiation. Preliminary arrangements were also made for T. H. Johnson of the Bartol Research Foundation to spend one or two months at the Observatory beginning early in August 1933 to carry out observations at the Observatory and in the general region of the Observatory with Geiger-Müller counter equipment in the test of theories relating to penetrating-radiation.

While no major construction was undertaken during the year, several improvements to the Observatory property were made. The main quarters building was leveled and provided with new foundations, the interior-room arrangements were somewhat altered, and the building was repainted inside and out. The attic was enlarged and improved by the addition of four large dormer-windows. Some new furnishings were provided for the living-room to add to the comfort of the staff. The office was enlarged by enclosing the porch on the east side of the building. The other buildings were maintained in as good condition as possible to combat the effects of the strong sunshine, and sundry small though necessary works undertaken, such as the planting of a garden and lawn in front of the auxiliary quarters, construction of concrete sidewalks, drains, etc.

Ledig continued in charge of the Observatory until December 1, 1932, when Cairns took charge. Seaton, radio operator, left Huancayo for the United States on August 20, 1932. Mansfield, assistant observer, arrived in Huancayo September 26. Wells arrived December 5 to take over the radio and ionized-layer work. Mrs. Cairns continued to give material assistance in the reduction of data, and Quintana continued in his position of observatory aid. Astete continued as clerical assistant.

The Observatory has continued to enjoy the helpful friendship of the officials of the Peruvian Government and of the local residents. Thanks are due also to the staffs of the American Embassy and Consulate at Lima, who have encouraged in every way these cordial relations with the Peruvian Government and who have so generously extended their facilities at all times.

Washington, United States—Registration of air-potentials and of positive and negative conductivity alternately by weeks was continued in the Deck

Observatory of the Laboratory at Washington until April 1933 by Gish, Torreson and Wiener. It is believed that the series at this place is now sufficiently long for the type of studies which would be justifiable under the conditions which prevail at this station. Furthermore, the more complete program of registration of air-potential and of both positive and negative conductivity using improved equipment designed and supplied by the Department is now well established at the Tucson Magnetic Observatory of the United States Coast and Geodetic Survey. Therefore, it seemed inadvisable to continue longer the regular registration at the present Washington site, which has become less favorable in recent years due to rapid encroachment of the residential section. At present the equipment is being left intact for possible use in connection with special investigations when that may be desirable.

COOPERATION WITH OTHER OBSERVATORIES

Apia Observatory, Western Samoa—Cooperation of the Department with the Apia Observatory (latitude $13^{\circ} 48'$ south, longitude $171^{\circ} 46'$ west) was maintained throughout the report-year. This cooperation, begun in 1921, is concerned chiefly with the atmospheric-electric program, although assistance relating to instruments, methods, discussion and maintenance in terrestrial magnetism and other geophysical subjects is given. Upon favorable recommendation of the Department, a further grant was obtained from the Rockefeller Foundation to insure continued operation during 1933 without serious interruption of the programs at Apia and Christchurch observatories.

A new la Cour balance was received December 1932 to replace the old vertical-intensity variometer which it had been found impossible to put again in operating condition. Observations with magnetometer and earth inductor were made approximately once each week for the control of the magnetic registrations.

Continuous records of atmospheric potential-gradient were obtained at two stations as during preceding years, namely, at the "Land Station" on the grounds of the Observatory and at the "Lagoon Station," the small hut over the shallow waters inside the coral reef about one kilometer from the Observatory. As in previous years, the potential gradient showed comparatively small seasonal ranges. The times of the maxima and minima agreed quite well with earlier observations which, on the average, gave the principal maximum at approximately 8^h with the secondary maximum at 19^h , and the principal minimum at 2^h with a secondary minimum at 15^h (165° west meridian time). The mean hourly values as deduced from the monthly means based on complete records obtained on 110 and 141 days of electrical character "0" at the Land and Lagoon stations, respectively, during the calendar year 1932 are given in the table on page 236 (the values given are based on the reduction-factors 1.00 for the Land Station and 0.63 for the Lagoon Station).

The monthly means of atmospheric potential-gradient at the Observatory for the calendar year 1932 are indicated in the table in which have been included the corresponding results for the year 1931 for the sake of comparison (the values are based on the reduction-factors as given and the values are those resulting from records obtained on days without negative potential).

*Summary of annual hourly values atmospheric potential-gradient, Apia
Observatory, Western Samoa, 1932*

Hour 165° WMT	Station		Hour 165° WMT	Station	
	Land	Lagoon		Land	Lagoon
<i>h h</i>	<i>v/m</i>	<i>v/m</i>	<i>h h</i>	<i>v/m</i>	<i>v/m</i>
0- 1	91	88	12-13	102	114
1- 2	88	88	13-14	97	107
2- 3	88	87	14-15	92	104
3- 4	87	85	15-16	92	90
4- 5	90	85	16-17	93	99
5- 6	94	90	17-18	97	103
6- 7	135	121	18-19	115	118
7- 8	194	211	19-20	145	152
8- 9	206	241	20-21	144	149
9-10	156	161	21-22	116	115
10-11	125	132	22-23	103	104
11-12	112	122	23-24	95	96
Annual means: Land 115 v/m, Lagoon 119 v/m					

*Summary of monthly mean values atmospheric potential-gradient, Apia Observatory,
Western Samoa, 1931 and 1932*

Station	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
		<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>
Land . . .	1931	89	79	98	111	108	114	104	117	103	113	117	104	
	1932	104	93	110	121	117	135	120	123	115	116	105	119	115
Lagoon..	1931	129	95	108	119	123	129	144	116	141	121	128	133	124
	1932	119	95	113	115	115	137	127	137	119	118	118	124	120

The program of work in meteorology included a complete set of surface observations made twice a day as in previous years and occasional measurements of the velocity of upper winds and upper clouds using pilot-balloons and a nephoscope. Synoptic reports collected at the Radio Station from various islands in the South Pacific were charted at the Observatory regularly day by day. Climatological values for the year 1932 at Apia are given in the table below.

Meteorological summary, Apia Observatory, Western Samoa, 1932

Month	Pressure	Temp.	Rainfall	Rel. hum. (9 a.m.)	Sunshine	Wind- velocity
<i>1932</i>	<i>inches</i>	<i>°F</i>	<i>inches</i>	<i>per cent</i>	<i>hours</i>	<i>miles/hr.</i>
Jan.....	29.743	79.8	21.34	82	157.5	3.4
Feb.....	29.780	79.8	13.70	78	193.1	3.7
Mar.....	29.783	79.7	14.20	77	210.6	3.4
Apr.....	29.770	79.2	12.81	83	158.8	2.7
May.....	29.856	80.6	3.80	76	251.1	4.2
June.....	29.867	78.3	1.31	76	239.1	2.3
July.....	29.836	79.2	2.42	76	247.7	3.4
Aug.....	29.880	78.8	5.99	77	254.4	3.4
Sept.....	29.865	78.6	6.27	74	231.1	3.5
Oct.....	29.857	79.7	6.77	73	248.1	4.6
Nov.....	29.800	79.6	20.09	79	191.6	3.0
Dec.....	29.756	80.2	15.24	79	215.8	2.8
Mean or total.....	29.82	79.5	123.9	77	2598.9	3.4

The annual reports of the Observatory, including the magnetic, seismological, meteorological and atmospheric-electric results, have been prepared and published for the calendar years 1930 and 1931, and manuscript for the report for the year 1932 is well under way. Two communications were prepared by J. Wadsworth, Director of the Observatory, for presentation at the Fifth Pacific Science Congress in June 1933. Glover completed several short papers dealing with changes in magnetic elements in relation to the seasons of the year and the number of sunspots.

During the report-year, J. Wadsworth was Director of the Observatory and had assigned as his assistants P. W. Glover and H. B. Sapsford.

Tucson, United States—Registrations of air-potential and of positive and negative air-conductivity, with the necessary controls, were made throughout the year by Observer-in-Charge Ludy and Observer Hershberger of the United States Coast and Geodetic Survey, cooperating with the Department. Because of the necessity of curtailment in personnel at the Observatory, it was not possible to complete the tabulations of the scaled values, and therefore the final compilations for the year 1932 are not yet complete. Since early in February, Carl A. Ludy has been engaged at Tucson by the Department on a part-time basis to reduce these records, and rapid headway has been made; at the end of the report-year a considerable part of the first scalings and tabulations for the calendar year 1932 had been completed by him.

Under the cooperative arrangement with the Mountain States Telephone and Telegraph Company, earth-current registration has been continued without important interruption.

International Polar Year Stations, College-Fairbanks and Point Barrow, Alaska—The Department has cooperated most actively in the realization of the participation of the United States in the International Polar Year of 1932-33 through the operation of two special stations, one designated as the College-Fairbanks Station in Alaska provided by an act of Congress appropriating \$30,000, and the second a station established at Point Barrow, Alaska, as a reoccupation of the station at that place occupied by the United States during the first International Polar Year of 1882-83.

The College-Fairbanks Station is under the direction of the United States Coast and Geodetic Survey and was made possible by the united efforts of the State Department, the Department of Commerce through its Coast and Geodetic Survey and Bureau of Standards, the War Department through its radio station at Fairbanks, the Navy Department through its Naval Research Laboratory, the Department of Agriculture through its Weather Bureau, the Carnegie Institution of Washington through its Department of Terrestrial Magnetism, the Alaska Agricultural College and School of Mines, the International Polar Year Commission, and contributions from individuals totaling over \$2600. The appropriation was not made available until July 1, 1932, but despite this the buildings were constructed and the instrumental equipment was installed so that the complete program of continuous registration was begun October 1, 1932.

The program at the College-Fairbanks Station is a most comprehensive one, including magnetic-variation and absolute measurements, earth-current records, detailed visual and photographic auroral observations, measurements of variations in magnetic vertical-intensity by the Mitchell loop-method, atmospheric potential-gradient, air-conductivity, ionic content,

Aitken nuclei-counts and radio measurements on the height of the ionized regions of the upper atmosphere. The last-named measurements together with meteorological observations on an enlarged and intensified program at the United States Weather Bureau station are being made at Fairbanks by H. B. Maris of the Naval Research Laboratory, who has the cooperation of the station of the Signal Corps of the United States Army there.

Sherman of the Department was assigned to the staff at the College-Fairbanks Station to look after the atmospheric-electric and earth-current work under the general direction of E. R. Johnson, Observer-in-Charge for the Coast and Geodetic Survey. Rooney of the Department was at College July 22 to October 13, 1932, and made preliminary arrangements and surveys for the buildings and for the installation of the earth-current lines and apparatus and of the atmospheric-electric equipment. Sherman, who was assigned from the Department for the full Polar Year, arrived at College July 31. In addition to the work above specified, Sherman had charge also of the installation and operation of the Mitchell vertical-intensity inductometer.

Among the electrical phenomena observed at the College-Fairbanks Station the measurement of earth-currents is being particularly stressed, using apparatus provided and installed by the Department; the records already received indicate that interesting data, both on diurnal variation and short-period disturbances, may be expected.

A large measure of the success attending this cooperative effort was the contact already established through earlier cooperation of the Department with the auroral observatory at College in charge of Professor Veryl R. Fuller of the Department of Physics of the Alaska Agricultural College and School of Mines. He has continued not only the special auroral work but has contributed much time to the various features of the other geophysical programs at the Polar Year Station. His report for the season 1931-32 was completed and prepared for publication.

The station at Point Barrow, Alaska, as indicated in last year's report, was established through the cooperation of the Department, the United States Weather Bureau, and the International Polar Year Commission. C. J. McGregor of the Weather Bureau, in charge of the Point Barrow Station, installed and operated the magnetograph and necessary absolute instruments supplied by the Polar Year Commission and the Department. Copies of magnetograms and radio advices so far received indicate that the magnetic work has been fully realized as planned and that it will form a valuable contribution to the International Polar Year data.

Cooperative work with other International Polar Year stations—The Department has been privileged to cooperate with other International Polar Year observatories. A magnetometer-inductor was supplied for control-observations at Cape Town, and some aid was secured to assist the University authorities in providing the necessary building to house the variation instruments loaned by the International Polar Year Commission.

Earth-current equipment as designed by the Department was supplied to the Meteorological Service of Canada for use at its Polar Year station at Chesterfield Inlet. Davies of the Department's staff was on furlough throughout the report-year and had charge for the Meteorological Service of Canada of the work being done at Chesterfield Inlet.

Upon the request of Dr. J. Valensuela, Director of the Meteorological Service of Chile, Ledig spent some time at Magallanes instructing the observers in certain details of control and absolute observations. He obtained also a series of simultaneous comparison observations between his C.I.W. magnetometer-inductor 26 and the Kew magnetometer and inductor used at the Observatory.

The Department has also cooperated extensively by supplying instructions and purchasing of equipment for other Polar Year stations. Equipment for installation of earth-current apparatus after the Department's design was purchased for the Geophysical Observatory at Tromsøe.

REDUCTION AND DISCUSSION OF OBSERVATORY-DATA

The compilation and preparation for publication of the magnetic data for the Watheroo and Huancayo observatories were continued by Johnston, McNish, Forbush and Miss Balsam with occasional assistance from Ennis, Scott, Hendrix and Miss Ennis. Because of an improvement in the formula for variation of horizontal-intensity scale-value with ordinate the mean hourly values at Watheroo during 1919 to 1930 were recomputed and retabulated, thus delaying publication of the volume of the Department's *Researches* giving Watheroo results for 1919-30. These recomputations, retabulations and redrafting of numerous graphs requiring change were finished and final manuscript is now complete. Good progress has been made on the corresponding manuscript covering the data obtained at the Huancayo Magnetic Observatory from 1922.

Pending the completion of the work on solar and lunar magnetic variations at Watheroo, 1919-30, according to the original scheme, similar work was begun by Miss Assmann for declination at Huancayo, 1922-30. Using the experience obtained in compiling the data for Watheroo, a new scheme was devised by Bartels, starting with a simplified harmonic analysis for each individual day. In this way much material will be available for research on the variability of the solar diurnal-variations, its relations to the lunar variations and its bearing on the ionization in the high atmosphere. Preliminary calculations were begun by Bartels to obtain, in the manner proposed by Adolf Schmidt, the deviations of consecutive daily means from their normal values for horizontal intensity at Watheroo. They will be used in a study of the post-perturbation.

The reduction and tabulation of the magnetic results (May 1928 to February 1929) from the first Byrd Antarctic Expedition were completed by Wallis, and the preparation of manuscript for accompanying text and discussion was well under way by June 30. A study of the relationship between aurora and magnetic disturbance as recorded at Little America was made, involving an attempt to correlate the directions and intensities of auroral displays with the directions and intensities of simultaneous magnetic disturbing forces; apparently the series of observations during the season of maximum auroral display—June, July and August—was too short to establish a definite correlation. Some progress was made using the Expedition's results in an investigation on a relation between magnetic disturbances and a hypothetical ring or vortex of electrified matter circu-

lating above the auroral zone, the probability of the existence of such a ring or vortex being suggested by the fact that magnetic disturbances are usually most violent in the regions near the auroral zones. Wallis also made a beginning on a comparison of particular magnetic disturbances as recorded at Little America and at other observatories distributed over the Earth.

The preparation by Wait and Torreson of atmospheric-electric records for publication has progressed steadily throughout the year. Calibration-curves for Watheroo conductivity-records for all months from 1923 to 1930 have been completed and monthly conversion-tables prepared. A form for tabulation of data suitable for direct reproduction in publication was designed. The method of electric classification or characterization of days was discussed, and recommendations have been prepared by Torreson and Wait, as well as by Gish, for presentation before the Lisbon Assembly of the International Union of Geodesy and Geophysics in September 1933. Based on certain findings made while working on the calibration-data, a revision of temperature-coefficients of the conductivity-apparatus was undertaken. From this it appeared that errors caused by variation in temperature are not sufficiently large to warrant the labor involved in applying temperature-corrections. Discussion of need of possible corrections for change in temperature for the Watheroo potential-gradient records resulted in a similar conclusion.

The compilation of reduction-factor data for Watheroo through 1930 was completed late in June 1933. Studies of the special potential-gradient observations obtained at Watheroo were made in connection with the discussion of reduction-factor data. In adopting values for January 1, 1924, to December 31, 1932, it was concluded that the reduction-factor observations, while generally satisfactory, do not warrant using a factor to two decimal places. This study, taking account of changes in environment and apparatus used, indicated that valuable information would be obtained from observations of space-charge at the standardizing station and that such observations should be made.

A good beginning has been made by Wait and Torreson on the study of conductivity calibration-data for Huancayo for the years 1924, 1925 and 1926.

The data on earth-potentials from Watheroo, Huancayo, Tucson and College were promptly checked and examined by Rooney when received, that a close control might be kept on factors which might escape the routine control at the observatories. The tabulation by groups as intended for publication has been kept practically current with the magnetic classification for the several observatories. The grouping of earth-current data is made on the basis of the magnetic characterization. This method was adopted some years ago after a study had showed that an independent classification, based wholly upon the character of the earth-current records, agreed so closely with the magnetic classification that apparently nothing was to be gained by independent classifications of the data for these two closely related phenomena. The comparison of the diurnal variation in earth-currents on the five international quiet and the five international magnetically disturbed days was extended by Rooney to include data from Huancayo for the years 1930 and 1931 and that from Tucson for the year

July 1931 to June 1932. The small but definite difference found in the similar comparison of data from Watheroo and Ebro for the common five-year period, 1924-28, is apparently borne out by the Tucson data. Those for Huancayo, however, show a departure which may be perhaps associated with other peculiarities of that station.

Ennis gave special attention to the development of graphical methods of treating data when preparing, with the assistance of Hendrix and Miss Ennis, the numerous graphs required for publication of observatory results. Such methods were developed to determine diurnal variations in inclination and in testing components X and Y and total intensity F . These also serve as plotting sheets for the hourly correction of the diurnal variations in their respective planes. Graphical methods were developed also for intensity scale-value and daily range determinations, this method being used in the revision of daily numerical magnetic-activity measures for the Watheroo and Huancayo observatories for 1928 to 1933 in accordance with the Crichton Mitchell scheme adopted in 1930 by the International Association of Terrestrial Magnetism and Electricity.

OCEANOGRAPHIC REDUCTIONS

The preparation of manuscript and graphs for the first volume on the physical and chemical oceanographic results gathered during the last cruise of the *Carnegie* has advanced rapidly during the year under the general supervision of the Acting Director. Good progress has been made also by various cooperating agencies in the examinations and reports of the biological collections.

The preparation by Ennis, with assistance of Hendrix and Miss Ennis, of the many charts and graphs based on the *Carnegie* observations in the Atlantic and Pacific oceans was completed in February. These show the vertical and horizontal distribution of physical, chemical and sounding-velocity characteristics, and also the mean salinity-temperature relations in 14 regions of the Pacific. Computations and charts were made to illustrate the current-systems at various levels down to 1500 meters in the Pacific. Graphs were also prepared to show the direction and velocity of the wind, based on pilot-balloon observations on the *Carnegie* at 171 stations in the Pacific.

During the year, Sverdrup, a Research Associate of the Institution, at Bergen, Norway, has been informed of the progress of the discussion of the oceanographic data from the *Carnegie* and has made additions to his and other manuscripts dealing with the results of observations, particularly in physical oceanography. He has also had opportunity to study the numerous oceanographic observations of the *Discovery* expeditions from the Antarctic waters in the Pacific and Atlantic oceans. These observations were discussed at the Geophysical Institute in Bergen by A. J. Clowes, oceanographer of the *Discovery* expeditions. His discussion has led to important results as to the currents through the Drake Passage and these results will have to be considered when undertaking the final revision of the manuscript dealing with the results of the *Carnegie* Cruise VII. The study of the *Discovery* observations led Sverdrup to undertake an examination of the importance of the wind to vertical circulation in the ocean. The

results of this examination were used to explain certain features of the Antarctic circumpolar current, but may also be applied when dealing with other current-systems.

Soule was designated senior oceanographer of the International Ice Patrol of the United States Coast Guard and took up his new work February 1, 1933. Between July 1932 and January 1933 he revised Sverdrup's manuscript on *Carnegie* results in physical oceanography, his own on sonic soundings and sounding-velocities, Thomson's on pilot-balloon work, and Graham's and Moberg's on chemical results. The tables of sonic soundings and sounding-velocities were prepared and checked, and a paper on "Sounding-velocities in the Pacific" to be presented at the Fifth Pacific Science Congress was completed by him.

Forbush completed the manuscript of his discussion on gravity work done on the *Carnegie*. His manuscript was revised by Dr. Vening Meinesz and Dr. F. E. Wright, both of whom had so generously cooperated in the arrangements for and installation of gravity-equipment on board the *Carnegie*.

Miss Clarke continued preparation of the manuscript of meteorological results obtained on Cruise VII of the *Carnegie* and completed all computations and compilations of data including the harmonic analyses of means of vapor-pressure according to selected areas. A preliminary survey of observations of evaporation was made. The depth of evaporation in millimeters was determined from changes in salinity according to formulæ developed by Wüst. More detailed study of these results remains to be made.

The examination of the bottom-samples collected by the *Carnegie* was continued at the Scripps Institution of Oceanography, under the direction of Dr. T. Wayland Vaughn, chiefly by Roger Revelle and E. M. Thorp. Some additional chemical analyses are being made (*a*) of the clay grades of one or more globigerina oozes for calcium and magnesium and (*b*) of the silt and clay grades of one or more red clays for silica, iron oxide, alumina, manganese oxide, calcia, magnesia and the alkalis. The first is to determine whether solution of CaCO_3 and possible replacement by MgCO_3 takes place in the finely divided material, and the second is to attempt to distinguish between the larger mineral constituents of red clays and the finely divided clay material, as well as to determine the distribution of manganese. Dr. Joseph A. Cushman is undertaking identification and report on foraminifera for certain deep-sea pelagic deposits (1000 to 5000 meters) of the south-eastern and south central Pacific—regions previously explored by the *Albatross*—from about 500 slides prepared from *Carnegie* bottom-samples by Revelle and which contain some 150 to 200 species. W. H. Dore, of the University of California, is making X-ray spectrograms of a series of selected mineral species.

Fenner, of the Geophysical Laboratory of the Institution, also has a report nearly completed on further studies of the samples reported upon last year by Piggot of that Laboratory.

Dr. A. Mann, research associate of the Institution, has nearly completed his report on the diatoms found in the *Carnegie* collections.

Graham was occupied throughout the year at the Hopkins Marine Station at Pacific Grove, California. He and Moberg of the Scripps Institution of

Oceanography finally revised the manuscripts of the chemical reports. He continued intensively his studies of the Dinoflagellata of the *Carnegie* plankton collection, his studies of this group being from the standpoints of taxonomy, geographic distribution and evolutionary significance of skeletal variations. About 650 camera-lucida working sketches were made, to be used in the final organization of the results. Sixty-eight more species were recorded and their distribution in the Atlantic studied. It was found that many of the taxonomic difficulties which have been encountered in the genus *Peridinium* may be attributed not only to the fact that there is frequently a wide variation within the species, but also to the lack of thoroughness in the descriptions and figures published in the past. Too frequently only the grosser features were observed and reported. For this reason a detailed study of the skeletal morphology was started on one of the commonest and most varying groups of the genus, the formenkreis *Peridinium depressum* sensu lato. A careful dissection is being made of all skeletal units, so that not only the plate pattern but also the details of the more obscure apical, girdle and sulcal regions will be brought to light. Exact information in the morphology of the genus *Peridinium* will be of the utmost importance in the study of the entire group Dinoflagellata. As in the previous year, most generous cooperation was extended in this work by the Hopkins Marine Station, particularly by Dr. W. K. Fisher and Dr. T. Skogsberg.

The relative density of plankton at *Carnegie* stations in the Pacific as determined from tow-net hauls was computed and a tabulation prepared for distribution to various men working on the *Carnegie* plankton collections. Graham prepared a paper on "The distribution of the plankton of the Pacific as related to some physical and chemical conditions of the water" for the Fifth Pacific Science Congress at Victoria and Vancouver, June 1 to 14, 1933, which he attended as a delegate of the Department.

Since last year's report, progress in identifications of biological specimens of the *Carnegie's* tow-net samples has been as follows: J. A. Maloney, Miss Doris M. Cochran and A. H. Clark, of the Smithsonian Institution, have submitted reports on isopods, lizards and echinoderms. S. F. Hildebrand, Senior Ichthyologist of the Bureau of Fisheries, reported progress in preliminary identification of the collection of young fish; already a fine flying-fish collection and other groups have been sorted out. A. L. Treadwell, of the Department of Zoology of Vassar College, reports that the sorting of annelids is nearly complete and that discussion is under way. C. B. Wilson is finding some interesting things in his study of the copepods. H. A. Pilsbry, of the Academy of Natural Science of Philadelphia, has turned over to C. M. Blake, of Massachusetts Institute of Technology, the collection of Cirripedia for report; Dr. Pilsbry will review Dr. Blake's report.

Good use was made of the experience gained in the *Carnegie's* cruises to continue active cooperation with various oceanographical enterprises. Complete tabulations of the *Carnegie* data on soundings, temperatures and salinities were assembled for Dr. G. Schott of the Deutsche Seewarte for use in his forthcoming monograph on the geography of the Pacific. Similar cooperation was given the International Hydrographic Bureau for the revision of the General Bathymetric Chart. Soule collaborated with F. Wenner, of the Bureau of Standards, in preparing specifications for a new model of

salinity bridge, no specifications having been in existence previously. Upon request of Thomas G. Thompson, Director of the Oceanographic Laboratories of the University of Washington, tables to facilitate determinations of density of sea-water from observed values of temperature and salinity, as developed in the Department by Ennis, were supplied. Advice regarding various oceanographic problems was given the United States Hydrographic Office for its proposed oceanographic program in Central American waters and a program was proposed for the U. S. S. *Ramapo* in the North Pacific. The United States Coast Guard was supplied with various memoranda and suggestions by Soule relating to the program. Fleming and Soule prepared a list of equipment and notes on methods and program for physical and chemical oceanographic investigations on the expedition of the Smithsonian Institution on E. R. Johnson's yacht *Caroline* in the neighborhood of the deep off Puerto Rico during January to March 1933.

INSTRUMENT-SHOP

A total of more than 12,000 hours of the time of the shop-personnel (Steiner, Lorz, Haase, A. Smith, and T. Huff), under C. Huff's superintendence, was devoted to the construction of new equipment and experimental apparatus, to repair and improvement of instruments, to building and grounds and to stock and special items.

The complete equipment to determine height of the ionized regions in the upper atmosphere, involving the design and construction of two sets of transmitters, receivers, oscillographs, constant-frequency apparatus, and power-equipment for the Huancayo and Watheroo observatories, was finished for manual operation. The transmitter consists of a power-unit and rectifier-panel operating from a 60-cycle, 115-volt supply and a master-oscillator, a buffer-amplifier, a power-amplifier and an antenna tuning-unit. The receiver is of the superheterodyne type, consisting of a power-unit and rectifier-panel, a high-frequency amplifier, an intermediate-frequency amplifier and a special direct-current amplifier for operating an oscillograph. The oscillograph-motor operates from a tuning-fork-controlled constant-frequency apparatus. These units were forwarded to Watheroo and Huancayo. Special power equipment for the operation of the above apparatus was designed, constructed and shipped to the Watheroo Magnetic Observatory.

A special optical bench for the purpose of making copies photographically of given automatic records and at the same time changing the ratio of ordinate-scale to abscissa-scale, is about 80 per cent complete and required the design and construction of a camera using an eleven-by-fourteen plate-holder. The main features of this equipment are a rigid cast-iron base and slides made by the Hendey Machine Company, on which are mounted the magnetogram to be photographed, the lens-mounting and the plate-holder mounting. The magnetogram-frame and the plate-holder frame may be rotated through precise angles and are of rigid construction. Accurate settings of the magnetogram-support, lens and plate-holder supports are possible to secure exact ratios between these units.

The extension to the Experiment Building included preparation of plans and details for the electric wiring, much of which is special, and the design of work-benches and other details. Considerable attention was given to.

overhauling instruments and equipment used at the observatories, in the field, and at the laboratory, to building and site improvements, maintenance and repairs, to preparing the annual exhibit and maintaining the exhibit at the National Academy of Sciences and to packing and forwarding equipment, appurtenances and supplies.

MISCELLANEOUS ACTIVITIES

Activities in scientific bodies and lectures—Tuve delivered a lecture on "The atomic nucleus and high voltages" before the Franklin Institute of the State of Pennsylvania, February 2, 1933, summarizing the seven years of research in atomic physics by the Department.

An introductory lecture on upper atmospheric physics was given by J. Bartels at Bad Nauheim on September 21, 1932, during the 8th annual meeting of the German physicists and mathematicians; this survey stressed the paramount importance of the magnetic variations for the study of the ionized atmospheric layer and of solar and terrestrial relationships.

Staff-meetings for the discussion of current progress in the Department's fields were held in its library biweekly from October to May. The personnel of the Division of Terrestrial Magnetism and Seismology of the United States Coast and Geodetic Survey took active part in these meetings, as well as interested men from the Fixed Nitrogen Laboratory of the United States Department of Agriculture, from George Washington University, from the Bureau of Standards, and from the Naval Research Laboratory.

Dr. A. E. Kennelly, research associate, attended the International Electrical Congress held at Paris, July 5-12, 1932. He conferred there with Dr. E. Mathias of the Institut de Physique du Globe and with Dr. J. Bartels, research associate, who as a representative of the Department also attended the session of the Congress relating to terrestrial magnetism and electricity, on the subject of magnetic units and unit names. Bartels also attended May 14-20, 1933, at Copenhagen, the meeting of the International Commission for the Polar Year of 1932-33 as proxy for Fleming.

Exhibits—During the Institution's annual exhibit December 1932, the Department's contribution was designed to show its approach to a better understanding of magnetic phenomena through investigation of the atomic nucleus. The disintegration-protons from an aluminum foil bombarded by polonium alpha-particles using the Department's design of sylphon Wilson cloud-chamber were shown, and neutrons from beryllium were demonstrated with the linear amplification-counter.

The Department took part in the exhibit of the Washington Academy of Sciences held at the Bureau of Standards March 23-24, 1933, which upon request of the American Chemical Society was continued during the following week through March 30. A flashing model to show magnetic diurnal-variation at the Watheroo Magnetic Observatory and moving graphs to show the diurnal variations of the fast and slow ions of the atmosphere were shown.

Conferences—Besides the conference on atomic physics above referred to, a conference was held December 12, 1932, at the Administration Building, under the chairmanship of Fleming, on the relation of the researches of the Department to other research activities of the Carnegie Institution. Fisk

gave a brief summary of his studies of isoporic changes and foci, which brought out extensive discussion, particularly as regards the relations to the work of the Geophysical Laboratory and to the geological structure of the interior of the Earth. Another aspect enlisting much interest was the relation of the researches of the Department on magnetic activity as a measure of solar activity and of the sunspot cycles with particular reference to the work of the Mount Wilson Observatory.

At another Institution conference, December 10, 1932, on the relations of studies of climatic changes to other activities of the Institution, various points of contact with the Department's investigations were discussed.

As a member of a special committee appointed in December 1932 by President Merriam (W. S. Adams, Fleming and Wright) to advise with him on ways and means of obtaining better coordination of cosmic-ray investigations receiving support from the Institution, Fleming took part in frequent conferences of the Committee at Washington and through correspondence and with the Institution's research associates R. D. Bennett, A. H. Compton, J. L. Dunham, R. A. Millikan, T. H. Johnson and H. N. Russell. Funds were made available to the Institution by the Carnegie Corporation and are being disbursed through the Department. Splendid cooperation is being shown by interested workers everywhere, as indicated in the report of the Committee (see pages 331 to 334).

Bauer memorial—To honor the memory of Louis A. Bauer, late director of the Department, the September 1933 number of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, of which he was founder and editor for many years, was made a special memorial number. Striking proof of the widespread contacts and friendships enjoyed by Bauer and of the high place held by him in his chosen fields was afforded by the large number and variety of articles received from all parts of the world for this volume.

Library—Of outstanding importance to the library has been the donation by Mrs. Louis A. Bauer of the late director's private library of 471 volumes and 1324 pamphlets. Among these publications are a number of early and rare volumes pertaining to the history and development of terrestrial magnetism and many valuable fundamental treatises on mathematics. Of special value is the large collection of pamphlets and reprints of articles which appeared in various domestic and foreign periodicals before the establishment of the Department and of which it is extremely difficult to obtain copies at the present time.

The number of volumes and pamphlets added to the library during the report year inclusive of the Bauer library amounts to 2550, bringing the total number to 21,532. As pointed out in previous reports, this figure gives a very inadequate idea of the total number of titles added to the card-catalogue during the year, since there are regularly carded, classified and incorporated by the librarian, H. D. Harradon, into the library indexes the titles of all current papers dealing with terrestrial magnetism and electricity as well as with other topics bearing on the present or projected work of the Department. The card-catalog thus constitutes a permanent and indispensable reference index to important material in scientific magazines which might otherwise be overlooked and which often proves to be of more immediate importance than some of the more conspicuous volumes which are on the

shelves of the library. As in previous years, an active part has been taken in preparing issues of the *Journal of Terrestrial Magnetism and Atmospheric Electricity* for publication, particularly editing of manuscripts in foreign languages and the preparation of progress-notes on current geophysical research. Abstracts and reviews of important publications have been written, and the detailed annotated bibliography of publications on terrestrial magnetism and electricity and allied subjects has been continued. Many articles and documents have been translated from various foreign languages.

Office—The growing needs of administrative work have increased the responsibilities in business management of the office and correspondence, but these have been handled efficiently by Chief Clerk Smith and Property Clerk Capello with the assistance of Kolar, Moats and Hendrix.

Kolar continued in charge of the files of official correspondence and of the stock of Department publications. The list of the latter for the year 1932, compiled by him, shows the total number of publications by the various members of the Department December 31, 1932, to be over 1200. Prompt distribution of reprints to persons on the mailing-list was continued; in this distribution the facilities extended by the International Exchange of the Smithsonian Institution were most helpful.

ABSTRACTS OF PUBLICATIONS, LECTURES, AND PROGRESS-REPORTS¹

For those investigations of which published accounts have appeared, abstracts are generally omitted. In a few cases, however, abstracts are here given because of the relatively greater importance and significance of the conclusions drawn in the papers. Abstracts of reports on progress of current researches are given since brief accounts of current work of individual members of the staff will be helpful to their colleagues in like fields by informing them of preliminary results in so far as they appear significant to current research in our fields.

Tides in the atmosphere. J. Bartels. *Sci. Mon.*, vol. 35, 110-130 (Aug. 1932).

Earth's magnetism records solar changes. J. Bartels. *Carnegie Inst. Wash., News Service Bull.*, vol. 2, 243-247 (1932).

Statistical methods for research on diurnal variations. J. Bartels. *Terr. Mag.*, vol. 37, 291-302 (Sept. 1932).

The usual method of research on diurnal variations is based on taking averages for a number of days. In this way, however, characteristic features, especially the significant variability of the phenomenon, will be overlooked. This paper develops, therefore, the general formulæ for the calculation of the variability of diurnal variations and, for its numerical and graphical representation by means of harmonic dial, two-dimensional standard deviation and probable ellipse. The procedure is applied to the diurnal variation of declination on quiet days at Huancayo Observatory in southern summer. The variability affects both amplitudes and phases of the sine-waves and is surprisingly large. Preliminary results of similar calculations for Watheroo Observatory are summarized, among others the remarkable dial for the 24-hourly wave in horizontal intensity, which indicates that

¹ The abstracts of progress-reports included in this section are only those not summarized in the preceding portion of the report.

the focus of the diurnal atmospheric current-system passes on some days several degrees of latitude north, on other days south of Watheroo.

Remarks on Dr. Kennelly's notes. J. Bartels. *Terr. Mag.*, vol. 37, 453-454 (Dec. 1932).
How changes on the Sun's surface are recorded by the Earth's magnetism. J. Bartels.
Sci. Mon., vol. 35, 492-499 (Dec. 1932).

Sonnenströme und Magnetstürme. J. Bartels. *Wissen u. Fortschritt*, vol. 6, 251-256 (Dec. 1932).

Kurzer Ueberblick über die Physik der hohen Atmosphäre. J. Bartels. *Zs. techn. Physik*, vol. 13, 611-616 (1932).

Ueberblick über die Physik der hohen Atmosphäre. J. Bartels. *Elektr. Nachr.-Technik*, vol. 10, Sonderheft, 40 pages with 42 illustrations (1933). [Presented at the meeting of the Heinrich-Hertz-Gesellschaft, Bad Nauheim, Sept. 21, 1932.]

This survey of upper-atmospheric physics gives a review and an extensive bibliography of our varied sources of information concerning the state and phenomena of the air at high levels. The topics are: Direct measurements by means of balloon ascents; high clouds; geometrical relations of radiation falling upon the Earth; light of the night sky; meteors; ozone; abnormal sound-propagation; composition and pressure of the air at different levels; earth-magnetic evidence bearing upon the upper atmosphere; ionizing and dissociating influence of monochromatic radiation absorbed in the atmosphere; Chapman's discussion of upper-air phenomena. The variations of terrestrial magnetism are discussed with special fulness, since they yield the most reliable and detailed knowledge about solar and terrestrial relationships.

L'activité du magnétisme terrestre et ses relations avec les phénomènes solaires. J. Bartels. C. R., Cong. Internat. d'Electricité, Paris, vol. 12, 77-88 (1932).

Verdunstung, Bodenfeuchtigkeit und Sickerwasser unter natürlichen Verhältnissen. J. Bartels. *Zs. für Forst-und Jagdwesen*, vol. 65, 204-219 (April 1933).

Mathematische Bearbeitung geophysikalischer und meteorologischer Beobachtungen. J. Bartels. [Fourteen lectures presented during 1932-33 winter-term at Berlin University.]

Einführung in die Geophysik. J. Bartels. [Twelve lectures presented during 1933 summer-term at Hamburg University.]

The variability of the diurnal magnetic-variation at the Watheroo Observatory. J. Bartels.

Harmonic dials for the 24-hourly waves on individual quiet summer days at Watheroo are plotted for declination (D) and vertical intensity (Z). On the dial for Z , a two-fold subdivision is made, separating days with large and small amplitudes and days with early and late occurrence of maxima. These subgroups of days are found to show the same peculiarities on the dial for D so that the D -dial can be regarded as produced by a systematic geometrical transformation of the Z -dial, and vice versa. This is a new argument for the conception of the diurnal magnetic-variation as an effect of a current system which, as a whole, undergoes large and significant changes from one day to the other. It will be important for the theory of the electric phenomena in the upper atmosphere to find out whether this close coordination is restricted to the solar diurnal-variation or can be traced in the lunar diurnal-variations also.

Quantum theory of dispersion. G. Breit. *Rev. Modern Phys.*, vol. 4, 505-576 (July 1932), and vol. 5, 91-140 (April 1933).

Isotope displacement in hyperfine structure. G. Breit. *Phys. Rev.*, vol. 42, 348-354 (Nov. 1, 1932).

The isotope-shift in hyperfine structure. G. Breit and J. E. Rosenthal. *Phys. Rev.*, vol. 41, 459-470 (Aug. 15, 1932).

Hyperfine structure in intermediate coupling and nuclear magnetic moments. G. Breit and L. A. Wills. (Abstract) *Phys. Rev.*, vol. 43, 1044 (June 15, 1933).

- Principal magnetic storms, Huancayo Magnetic Observatory, October to December 1932 and January to March 1933. J. E. I. Cairns. *Terr. Mag.*, vol. 38, 70 (Mar. 1933) and 152 (June 1933).
- American *URSI* broadcasts of cosmic data. K. B. Clarke. *Terr. Mag.*, vol. 37, 409-411 (Sept. 1932); 484-487 (Dec. 1932); vol. 38, 60-63 (Mar. 1933); 148-151 (June 1933).
- Semi-diurnal variation of barometric pressure over the oceans. K. B. Clarke. *Q. J. R. Met. Soc.*, vol. 59, 67-70 (Jan. 1933).
- Reduction of meteorological data from Cruise VII of the *Carnegie*. K. B. Clarke. *Nat. Res. Council, Trans. Amer. Geophys. Union*, 14th annual meeting, 79-80 (June 1933).
- Meteorological results of Cruise VII of the *Carnegie*, 1928-1929. K. B. Clarke. [Prepared for the Fifth Pacific Science Congress, June 1933.]

The meteorological program of Cruise VII of the *Carnegie* (1928-29) and the instruments used in obtaining hourly values of sea-temperature, air-temperature, vapor-pressure, relative humidity and atmospheric pressure are described. Summaries of the results from studies of the relations between sea- and air-conditions, and of diurnal variations, particularly of atmospheric pressure, are given. Methods for obtaining and reducing evaporation measurements from 23 series of observations taken on the *Carnegie* are briefly discussed.

Diurnal waves of atmospheric pressure computed from observations made on Cruise VII of the *Carnegie*. K. B. Clarke. *Beitr. Geophysik*, vol. 39, 337-355 (1933).

The instruments and methods used in obtaining hourly values of atmospheric pressure on the *Carnegie*, 1928-29, are described. By averaging hourly values to give the mean diurnal-variation for every ten degrees of latitude, correcting for non-cyclic change, and subjecting the diurnal curves to harmonic analyses, amplitude and phase of the 24-hourly, 12-hourly, 8-hourly and 6-hourly waves are obtained. The coefficients of these waves are represented on harmonic dials. The 24-hourly wave is briefly discussed. The coefficients of the 12-hourly wave are compared with other oceanic observations, with Simpson's empirical values, and with values from ocean-islands. The 8-hourly and 6-hourly oscillations are also discussed. The 6-hourly wave from *Carnegie* data is compared with results of Pramanik's study.

- On the technique and design of Wilson cloud-chambers. O. Dahl, L. R. Hafstad and M. A. Tuve. *Rev. Sci. Inst.*, vol. 4, 373-378 (July 1933).
- Magnetic activity—numerical magnetic character of days. C. R. Duvall. *Terr. Mag.*, vol. 37, 261-267 (Sept. 1932).
- Note on the computation of density of sea-water and on corrections for deep-sea reversing-thermometers. C. C. Ennis. *Hydrogr. Rev.*, vol. 10, 131-135 (May 1933).
- Use of regional constant correction-factors for reduction of echo-soundings. C. C. Ennis. [Prepared for the Fifth Pacific Science Congress, June 1933.]
- The unsymmetrical distribution of magnetic secular variation. H. W. Fisk. *Terr. Mag.*, vol. 37, 235-240 (Sept. 1932).
- Eclipse observations of the Department of Terrestrial Magnetism, Carnegie Institution of Washington. H. W. Fisk. (Abstract) *Jour. Wash. Acad. Sci.*, vol. 23, 155 (Mar. 15, 1933).

Opportunity was taken during the total solar eclipse of August 31, 1932, to collect additional data bearing upon a possible effect upon the magnetic field due to the passage of the Moon's shadow across the Earth.

The observations consisted of eye-readings of declination only, using the ordinary field-magnetometer. Three stations were established within the belt of totality, two being about equally distant from the center line in northern Vermont and western Maine, in approximately the same latitude,

the third being near the center line, farther south, on the New Hampshire-Maine border.

The days preceding the eclipse were characterized by a moderate magnetic storm, which had nearly disappeared by the day of the eclipse. A comparison of the graphs drawn from the observations at the three stations showed a very close identity of curves for the three field-stations, and these were very similar in detail to the curves taken from the Agincourt and Cheltenham magnetograms. An interesting feature apparent on each of the curves was a small but very distinct fluctuation which occurred immediately after totality at the field-stations and coincided quite exactly with the time the shadow crossed the New England coastline and passed out over the sea. The occurrence of this small disturbance after many hours of normal diurnal movement was quite startling and its coincidence with totality was very suggestive of a possible connection, although it is recognized that the coincidence may have been entirely fortuitous.

Previous investigations have led to the conclusion that the eclipse effect on the magnetic field is that of a diminution in the expected departure of a value of an element from its daily mean value, and that this takes place somewhat gradually during the entire interval during which the Moon's shadow falls upon the Earth. Superimposed upon this general effect there has been detected another effect corresponding to the local eclipse interval. However, because of other irregularities which are continually occurring and which are entirely independent of the eclipse, it is only by a discussion of a large mass of data that conclusions may be safely reached.

- Distribution of magnetic observatories and secular-variation stations. J. A. Fleming. *Terr. Mag.*, vol. 37, 245-251 (Sept. 1932).
- Distribution à travers le monde des observatoires magnétiques et des stations pour l'étude de la variation séculaire. J. A. Fleming. C. R., Cong. Internat. d'Electricité, Paris, vol. 12, 18-28 (1932).
- Thirteenth annual meeting of the American Geophysical Union. J. A. Fleming. *Science*, vol. 76, 346-349 (Oct. 14, 1932).
- Louis Agricola Bauer. J. A. Fleming. *Beitr. Geophysik*, vol. 37, 129-130 with portrait (1932).
- The seismological station at the Huancayo Magnetic Observatory in Peru. J. A. Fleming. *Bull. Seis. Soc. Amer.*, vol. 22, 263-269 (December 1932); (abstract) *Earthquake Notes*, vol. 4, 10-11 (Sept. 1932).
- Summary of the year's work, Department of Terrestrial Magnetism, Carnegie Institution of Washington. J. A. Fleming. *Terr. Mag.*, vol. 37, 455-462 (Dec. 1932).
- Progress-report on compilation of oceanic results, *Carnegie* cruise, 1928-29. J. A. Fleming. Rep. Comm. Submarine Configuration and Oceanic Circulation, Nat. Res. Council, 83-88 (1932).
- Oceanographic work in the polar regions. J. A. Fleming. Rep. Comm. Submarine Configuration and Oceanic Circulation, Nat. Res. Council, 88-90 (1932).
- Annual report of the Director of the Department of Terrestrial Magnetism. J. A. Fleming. *Carnegie Inst. Wash. Year Book*, No. 31, 1931-1932, 223-277 (1932).
- Harlan Wilbur Fisk. J. A. Fleming. *Science*, vol. 77, 80-81 (Jan. 20, 1933).
- International Union of Geodesy and Geophysics. J. A. Fleming. *Standards Year Book*, 1933, Dept. Comm., Bur. Stan. Misc. Pub. No. 139, 4-5 (1933).
- American Geophysical Union. J. A. Fleming. *Standards Year Book*, 1933, Dept. Comm., Bur. Stan. Misc. Pub. No. 139, 5-8 (1933).
- Studies in nuclear physics. J. A. Fleming. *Science*, vol. 77, 298-300 (Mar. 24, 1933).
- Terrestrial magnetism and electricity. J. A. Fleming. *American Year Book for 1932*, New York, 699-703 (1933).
- The fourteenth annual meeting of the American Geophysical Union. J. A. Fleming. *Science*, vol. 77, 607-609 (June 23, 1933).
- Progress-report on the International Polar Year of 1932-1933. J. A. Fleming. Nat. Res. Council, Trans. Amer. Geophys. Union, 14th annual meeting, 146-154 (June 1933).
- Magnetic investigations of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, May 1932 to April 1933. J. A. Fleming. Nat. Res. Council, Trans. Amer. Geophys. Union, 14th annual meeting, 160-165 (June 1933).

- The Huancayo seismograph station in Peru. J. A. Fleming. Nat. Res. Council, Trans. Amer. Geophys. Union, 14th annual meeting, 310-311 (June 1933).
- Transactions of the American Geophysical Union, fourteenth annual meeting, April 27-29, 1933. J. A. Fleming, Editor. Nat. Res. Council, 521 pp. (June 1933).
- International cooperation in scientific research in geophysics. J. A. Fleming. [Prepared for meeting of the Pan-American Institute of Geography and History in Rio de Janeiro, Brazil, Dec. 1932.]
- Report on progress of the International Polar Year. J. A. Fleming. [Prepared for the Division of Geology and Geography of the National Research Council, Apr. 22, 1933.]
- Report on the International Union of Geodesy and Geophysics and American Geophysical Union. J. A. Fleming. [Prepared for the Division of Foreign Relations of the National Research Council, Apr. 23, 1933.]
- The relations of magnetic and electric work in the Pacific Ocean to the Polar Year campaign, 1932-33. J. A. Fleming. [Prepared for the Fifth Pacific Science Congress, June 1933.]
- The distribution and need of additional magnetic observatories and secular-variation stations in the Pacific Region. J. A. Fleming. [Prepared for the Fifth Pacific Science Congress, June 1933.]
- Living high in the Andes to solve the many secrets of the Earth's magnetism. S. E. Forbush. Boston Evening Transcript, Nov. 26, 1932.
- Apparent vertical earth-current variations at the Huancayo Magnetic Observatory. S. E. Forbush. Terr. Mag., vol. 38, 1-11 (Mar. 1933).

Continuous photographic registration at the Huancayo Magnetic Observatory, in Peru, of the potential-difference between electrodes at the top and bottom of a dry well about 46 meters deep indicated apparent changes in the vertical earth-potential gradient. Comparatively short time-changes, during magnetic disturbances, occurred simultaneously on the magnetic horizontal-intensity record, on the horizontal earth-current records, and on the record of the potential-difference between the electrodes in the well. For changes occurring in intervals of about ten minutes or less, an increase of current toward the northwest in the horizontal plane was always associated with an increase of current downward in the well; similarly an increase toward the southeast was always associated with an increase upward in the well. For all the changes investigated, the increase of current in the horizontal plane was always approximately toward the northwest or toward the southeast. It is concluded that at this station the distortion of the normal horizontal earth-current lines of flow by horizontal and vertical variations of resistivity near the well may be the sole source of the observed variations in the vertical direction and that the apparent vertical earth-current probably does not cross the Earth's surface.

- Gravity-determinations on the *Carnegie*. S. E. Forbush. [Prepared for the Fifth Pacific Science Congress, June 1933; also presented before the Philosophical Society of Washington, Jan. 28, 1933.]
- Report on gravity-determinations on the *Carnegie*. S. E. Forbush.

Attention is called to the necessity of more and better distributed gravity determinations for deriving accurately the figure of the Earth, and also to the importance of detailed gravimetric surveys in regions of tectonic disturbances. The valuable information to be gained from such surveys is indicated by a brief résumé of the results obtained by Dr. F. A. Vening Meinesz in the Dutch East Indies and in the West Indies. The fundamental principles of the Meinesz apparatus for determining gravity at sea are described. Sufficient of the mathematical theory of the apparatus (following Meinesz) is given to facilitate discussion of the behavior of the apparatus on the *Carnegie* and of the difficulties encountered in making the reductions. Several factors which may have operated to increase the amplitudes of the pendulums to the point where observations could not be obtained are

discussed in detail. It is concluded that had the apparatus been oriented with the plane of the pendulums parallel to the ship's keel instead of at right-angles to it, the probability of obtaining successful observations would have been greatly increased.

Considerable attention is given to the constancy of the chronometer-rates and methods are given providing some estimate of their reliability. Problems peculiar to the *Carnegie* gravity-records are discussed. The gravity-values obtained at five stations are tabulated, as also those at two of the stations obtained by Meinesz. The results of the isostatic reductions made by the United States Coast and Geodetic Survey are included, together with a brief discussion of the isostatic anomalies. The conclusion is reached that other oceanographic expeditions using surface vessels should include gravity-determinations in their observational programs.

Les courants électriques naturels de l'écorce de la Terre et leur rapport avec le magnétisme terrestre. O. H. Gish. C. R., Cong. Internat. d'Electricité, Paris, vol. 12, 89-109 (1932).

Observed air-earth current and maintenance of Earth's charge. O. H. Gish. Terr. Mag., vol. 37, 361-362 (Sept. 1932).

The anomalous mountain-effect in earth-current measurements. O. H. Gish. Terr. Mag., vol. 37, 407-408 (Sept. 1932).

Use of geoelectric methods in search for oil. O. H. Gish. Bull. Amer. Ass. Petrol. Geol., vol. 16, 1337-1348 (Dec. 1932).

Associated problems in hydrology and terrestrial electricity. O. H. Gish. Nat. Res. Council, Trans. Amer. Geophys. Union, 14th annual meeting, 37-40 (June 1933).

The problem of vertical earth-currents. O. H. Gish. Nat. Res. Council, Trans. Amer. Geophys. Union, 14th annual meeting, 144-146 (June 1933).

Three classes of electric currents which apparently flow between the Earth and the atmosphere are subjects under investigation by geophysicists. These are: (a) "The air-earth current," which is shown to exist by electrical measurements made in the atmosphere; (b) "the magnetic line-integral currents," which are indicated by analyses of magnetic measurements made at the Earth's surface; and (c) "the vertical earth-currents," which are thought by some investigators to be indicated by measurements of the difference of potential between two points of earth between which there is a difference of altitude. The measurements for class (a) appear to deny the existence of classes (b) and (c). This anomalous situation is discussed and, especially in the case of the problems presented by class (c), an attitude is recommended, which heretofore has been overlooked or at least neglected.

The effects of turbulent air-flow in Ebert ion-counters and Gerdien conductivity-apparatuses. O. H. Gish.

The quantitative theory of the Ebert type ion-counter and the Gerdien type conductivity-apparatus involves the assumption of lamellar air-flow through the cylindrical condensers which constitute a common feature of these apparatuses. Some experimental results, however, brought up the question whether the theory is sufficiently comprehensive. Turbulence in the air-stream seemed to be the only important factor which was not taken into account. Examination indicated that turbulent flow doubtless occurs in condensers of the dimensions and with the average air-stream velocities generally used in these apparatuses. Since in both apparatuses, ions are driven transversely to the air-stream, positive to one element of the condenser and negative to the other, there tends to arise a concentration-gradient which turbulence, however, counteracts. Thus, turbulence opposes the electric field in the condenser. The result is to increase the effective resistance

or decrease the conductance of the condenser. However, when turbulence is neglected, the conductance of a given condenser is considered to vary only with the conductivity of the air, or conductance $= 4\pi\gamma\lambda$, where λ is conductivity from ions of one sign and γ is considered to be a constant, or form-factor for a given condenser. This constant has frequently been designated as the "capacity of the portion of the insulated system exposed to the air-current." Its value has, in fact, been determined for the Gerdien conductivity-apparatus as a capacitance. It seems likely, however, that on account of the effect of turbulence such a determination may be appreciably in error. Because this factor is doubtless dependent on turbulence, and since in certain types of electrodes (such, for example, as is used in the Swann modification of the Ebert ion-counter), the expression "capacity of the portion of the insulated system exposed to the air-current" becomes meaningless, the term conductance-factor is recommended.

It is believed that a number of rather puzzling results obtained with ion-counters and conductivity-apparatuses which appear in the literature can be attributed to effects of turbulence. The determination of mobility or the setting of certain limits for such values are likely also to be considerably in error owing to the neglect of the effects of turbulence. The matter apparently deserves careful experimental investigation, and it seems likely that the "conductance-factor" required for the Gerdien conductivity-apparatus must be determined by means other than those heretofore employed.

Seasonal magnetic variations at Apia. P. W. Glover. Terr. Mag., vol. 37, 303-308 (Sept. 1932).

Correlation between sunspot-activity and daily ranges of terrestrial magnetic elements at Apia, Western Samoa, 1905 to 1929. P. W. Glover. Terr. Mag., vol. 38, 107-108 (June 1933).

The distribution of the plankton of the Pacific as related to some physical and chemical conditions of the water. H. W. Graham. [Prepared for the Fifth Pacific Science Congress, June 1933.]

A tentative generalized picture of the distribution of plankton over the Pacific is as follows: North of 40° or 45° north there is a very abundant plankton which extends in the east southward along the west coast of North America. In the South Pacific bordering the Antarctic there is an abundant plankton which extends in the east northward along the west coast of South America. The rest of the South Pacific and the tropical Pacific have medium quantities of plankton, while the central portion of the North Pacific supports an extremely poor production of plankton.

On the last cruise of the *Carnegie* a positive correlation was found in the Pacific between the phosphate-content of the upper water-layers and quantity of phytoplankton contained therein. A study of other correlations and of subsurface conditions indicated that the differential distribution of plankton in the open Pacific is caused largely by differences in the amount of vertical circulation in the upper few hundred meters. This circulation is probably the chief factor in the renewal of the nutrient salts in the phytosynthetic zone.

Magnetic secular-variation in the Pacific Region. J. W. Green. [Prepared for the Fifth Pacific Science Congress, June 1933.]

The paper describes the methods being followed in final discussion of magnetic data obtained during the cruises of the *Galilee* (1905-08) and *Carnegie* (1909-29) to determine secular variations. Following some general remarks on secular variation, the method selected as most suitable

and workable of several considered is explained in detail. Certain assumptions involved in the use of published isomagnetic charts to reduce the time required in least-square adjustments are described. These adjustments give values at track-intersections depending upon groups of observations preceding and following the ones nearest the intersection. It is found that this adjustment is quite sufficient within the limit of error of observation when it includes second-order terms for the rate of change of an element with change in geographical position. The reductions completed yield much more consistent values for secular change than those obtained from the preliminary compilations made during each cruise. The selected areas of the Pacific for which the computations are completed and those for which the computations are yet to be made, as well as the relation of the several cruises to these areas, are shown by two charts.

The application of the FP-54 pliotron to atomic disintegration-studies. L. R. Hafstad. *Phys. Rev.*, vol. 44, 201-213 (Aug. 1, 1933).

The possibility of utilizing the high inherent sensitivity of the FP-54 pliotron in nuclear disintegration studies, particularly in connection with the problem presented by the discrepancies in present experimental results on resonance-disintegration of aluminum, has been investigated. The usable sensitivity of the tube is found to be limited only by a residual fluctuation of about $\pm 3 \times 10^{-5}$ root-mean-square volt. A theoretical consideration shows that this fluctuation is of the order of magnitude to be expected from shot-effects and thermal effects in the grid-circuit, and further that a thermal effect of the same magnitude should be present in the Hoffman electrometer. Preliminary observations on the range of beryllium-neutron recoil-protons gave a value of about 45 cm., in agreement with Chadwick's result. Preliminary observations on the disintegration of aluminum using a thick target gave the following results. The yield was about 20 protons of ranges between 30 and 50 cm. per 10^{-8} alpha-particles, in good agreement with the result of Pose. Groups with ranges of about 30 cm. and 60 cm. were found to show the abrupt drop in the absorption-curve characteristic of Pose's results. (The present series of observations failed for purely technical reasons to give a conclusive result in the range 45 to 55 cm.) A "differential" curve neglecting the smallest deflections gave a maximum in the region 45 to 50 cm., suggesting the presence of a strong group of about this range. A consideration of the geometrical arrangements used by various investigators leads to the conclusion that Steudel's failure to find resonance can be attributed to the large angles between incident alpha-particles and emitted protons permitted by his apparatus. A discussion of other discrepancies in experimental data on the basis of FP-54 results must await further observations with a more suitable alpha-particle source.

The resonance-disintegration of aluminum. L. R. Hafstad. [Presented at the Physics Colloquium, Johns Hopkins University, Baltimore, Maryland, Nov. 17, 1932.]

The ultimate limitations on the measurement of extremely small currents. L. R. Hafstad. [Presented at the Physics Colloquium, Johns Hopkins University, Baltimore, Maryland, Mar. 9, 1933.]

Expedition for study of the Earth's magnetic behavior. E. Hanson. *Carnegie Inst. Wash., News Service Bull.*, vol. 3, No. 6, 37-42 (1933).

Twenty thousand miles through South America. E. Hanson. *Discovery*, vol. 14, 193-196 (June 1933).

The Amazon and Andes today—a region of social regression. E. Hanson. [Presented before the American Geographical Society, New York, New York, Mar. 21, 1933; also before the Explorers Club, New York, New York, Mar. 24, 1933.]

- Principal published papers of Louis A. Bauer. H. D. Harradon. Terr. Mag., vol. 37, 220-224 (Sept. 1932).
- Prof. Harlan W. Fisk. H. D. Harradon. Nature, vol. 131, 229-230 (Feb. 18, 1933).
- Harlan Wilbur Fisk, 1869-1932. H. D. Harradon. Terr. Mag., vol. 38, 55-58 (Mar. 1933).
- List of recent publications. H. D. Harradon. Terr. Mag., vol. 37, 416-420 (Sept. 1932); 496-503 (Dec. 1932); vol. 38, 73-78 (Mar. 1933); 155-160 (June 1933).
- The interaction of a valence electron with a closed shell. M. H. Johnson and G. Breit. (Abstract) Phys. Rev., vol. 43, 1047 (June 15, 1933).
- The equipment and work of the Huancayo Magnetic Observatory. H. F. Johnston. [Prepared for the Fifth Pacific Science Congress, June 1933.]
- Navigational methods used on the *Carnegie*. H. F. Johnston. [Lecture before the Washington Squadron of United States Power Squadrons, Apr. 15, 1933.]
- Variations du champ magnétique terrestre aux observatoires de Watheroo et de Huancayo et leurs relations avec les systèmes de courants à l'intérieur et au voisinage de la Terre. H. F. Johnston and A. G. McNish. C. R., Cong. Internat. d'Electricité, Paris, vol. 12, 41-52 (1932).
- Cosmic disturbances of the Earth's magnetic field and their influence upon radio communication. A. E. Kennelly. Sci. Mon., vol. 35, 42-56 (July 1932).
- Radio during eclipses. Atmospheric disturbances, intensity of signals, delayed echoes, and goniometry. A. E. Kennelly. Electronics, vol. 5, 248-249 (Aug. 1932).
- Notes on the July 1932 meeting of the Committee on Symbols, Units, and Nomenclature of the International Union of Pure and Applied Physics, to discuss magnetic units. A. E. Kennelly. Terr. Mag., vol. 37, 447-453 (Dec. 1932).
- Magnetic definitions from the circuital standpoint. A. E. Kennelly. Proc. Amer. Phil. Soc., vol. 72, 39-55 (1933).
- Observations of the effective height of the Kennelly-Heaviside layer and field intensity during the solar eclipse of August 31, 1932. G. W. Kenrick and G. W. Pickard. Proc. Inst. Radio Eng., vol. 21, 546-566 (Apr. 1933).
- List of publications of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, 1932. J. J. Kolar. Carnegie Inst. Wash., 9 pp. (Dec. 31, 1932).
- Optical dispersion. S. A. Korff and G. Breit. Rev. Modern Phys., vol. 4, 471-503 (July 1932).
- Principal magnetic storms, Huancayo Magnetic Observatory, January to June 1932 and July to September 1932. P. G. Ledig. Terr. Mag., vol. 37, 414-415 (Sept. 1932) and 491 (Dec. 1932).
- Sources of errors in the determination of the potential gradient of the Earth's electric field. A. G. McNish. Terr. Mag., vol. 37, 439-446 (Dec. 1932).
- Principles of statistical analysis occasionally overlooked. A. G. McNish. Jour. Frank. Inst., vol. 215, 697-703 (June 1933).
- The apparent effect of magnetic activity upon secular change. A. G. McNish. Nat. Res. Council, Trans. Amer. Geophys. Union, 14th annual meeting, 139-144 (June 1933).

The 11-year variation in the horizontal component of the Earth's magnetic field at various observatories is investigated. It is found to be due to the accumulation of post-perturbation depressions during magnetically active years and, as these are associated with solar phenomena, the cause of the apparent effect of solar activity upon magnetic secular change is thus evident. The suggestion of Chapman that a magnetic storm, since it increases the flux through the Earth, may directly contribute to the secular change is not supported by the results of this study.

The method of investigation consists of forming second differences of the annual values of horizontal force and of magnetic activity as measured by the interdiurnal variability, and correlating them. The advantages of this method of analysis for the investigation of supposedly correlated cyclic phenomena are discussed.

Magnetic observations from Bombay, Batavia, Honolulu, Tucson, Cheltenham, Potsdam-Sedden and Sitka are used. It is found that the correlation

of the second differences of mean annual values of horizontal magnetic force and magnetic activity is always negative, and roughly representable as a linear function of the geomagnetic latitude, having large values near the geomagnetic equator and approaching zero toward the geomagnetic poles. Statistical analysis of cosmic-ray data taken with a tube-counter. A. G. McNish.

Various tests for the reliability of data taken with a tube-counter have been compiled and interpreted with respect to their application to cosmic-ray data. Although the accuracy of such observations may be defined from considerations of *a priori* probability, these measures of precision should not be used to demonstrate the reality of phenomena unless they are supported by the dispersion of the observed residuals. High agreement between *a priori* and *a posteriori* probability is indicative of fair operating conditions so that considerable weight may be placed upon conclusions drawn from series of data in which this occurs.

Statistics of the Aitken nuclei-counter. A. G. McNish.

The theories of sampling underlying the operation of the Aitken nuclei-counter have been investigated from a theoretical and from an empirical point of view. The theoretical considerations lead to the expectation of a frequency distribution obeying Poisson's law of low probability. Selecting series of counts taken at various times at the Department which yielded means in approximate agreement, a frequency polygon was formed which showed excellent agreement with that predicted from the Poisson law. Having established the sampling theory involved, it follows that greater accuracy is achieved by taking large samples of air into the expansion chamber so that the statistical fluctuations of the number of particles in the sample will be small, even though this may lead to considerable observational uncertainty in accurately observing the number of particles precipitated.

Measurement of the charge passing during a lightning flash. A. G. McNish.

An attempt has been made to ascertain by magnetic means the charge passing during a lightning flash. Owing to their low damping the la Cour magnetic variometers in operation at our Huancayo Observatory are deflected by lightning discharges. Considering the variometers as suspended-magnet-type ballistic galvanometers, it is possible to deduce the charge passing at a known distance to produce these deflections. Preliminary computations indicate that the magnitude of discharges which have been observed agree very well with the results which have been obtained by other means. However, exact computation of the charges passing during the flash have not yet been possible, owing to Maxwellian displacement-currents which must also be effective.

Principal magnetic storms, Watheroo Magnetic Observatory, January to June 1932, July to September 1932, October to December 1932, and January to March 1933. W. C. Parkinson. *Terr. Mag.*, vol. 37, 415 (Sept. 1932), 491 (Dec. 1932), and vol. 38, 70 (Mar. 1933), 152 (June 1933).

Terrestrial magnetism at the Watheroo Magnetic Observatory. W. C. Parkinson. [Prepared for the Fifth Pacific Science Congress, June 1933.]

Problems of terrestrial electricity which future observations in the Pacific Region will help to solve. W. C. Parkinson. [Prepared for the Fifth Pacific Science Congress, June 1933.]

Watheroo Magnetic Observatory, in Western Australia, established by the Carnegie Institution of Washington and operated by its Department of

Terrestrial Magnetism, has been engaged in terrestrial-electric measurements since 1922, at which time continuously recording conductivity-apparatus of the Gerdien type was installed. In 1923 recording of earth-current potentials was begun, and in 1924 apparatus for recording potential gradient was put into operation. Curves of annual and diurnal variation, based on data obtained with these instruments between 1924 and 1930, are presented and briefly discussed. It is pointed out that the annual variation in potential gradient agrees in phase with similar curves obtained over the Pacific Ocean by the vessel *Carnegie* and at land stations in the northern hemisphere. It is suggested that atmospheric pollution at Watheroo, affecting the atmospheric conductivity and hence affecting the potential gradient, may contribute to the agreement thus found. The curve for the diurnal variation in potential gradient in the "dry" season is shown to have the universal character discovered by Mauchly from *Carnegie* observations. The "wet" season curve, however, has peculiar features which are still under investigation. The diurnal variation of the ratio of positive to negative conductivity appears to be influenced by a daylight and night effect, the minimum ratios being found in the daylight hours and persisting for a longer period in the summer than in the shorter period of daylight in the winter. The results discussed emphasize the need of future wide distribution for data in terrestrial electricity over the region of the Pacific Ocean and its surrounding countries.

The distribution of mass in marine compasses. W. J. Peters. Terr. Mag., vol. 37, 317-320 (Sept. 1932).

Compass-errors in pendulous swinging. W. J. Peters.

Numerous experiments have been made with a standard ship-compass in the automatic swing especially for the purpose of detecting some relation between the magnitude of the compass-card oscillations and the deviation. They both depend more or less on the same conditional data, amplitude of swing, heading or course, magnetic moment, moment of inertia, etc. Since the magnitude of compass-card oscillations for any one station at sea will appear in the series of readings that are evenly distributed over the usual interval of say 5 to 10 minutes, it would seem that the deviation might be deduced from the oscillations which are shown by the original records. Oscillations at sea might be masked to some extent, in the actual readings, by effects of trigonometric conditions, but it is possible they may be negligible in determining the very small quantity representing the deviation. Tables of results for a standard liquid compass have been prepared showing the card-errors on 8 and on 16 headings with various amplitudes and radii of swinging motion.

After improvements had been made in the mechanical operation of the swing and in the methods of experiment, the outstanding fact revealed was a periodic sliding of the sapphire cap upon iridium point of the pivot in phase with the motion of the swing. The sliding motion is made possible apparently by the buoyancy of the float and the shape of the bearing-surfaces of cap and pivot. The result of the sliding motion is to give oscillations differing by amounts varying from 0° to 1.8° on different headings as read simultaneously by the forward and after lubber-lines for practically the same amplitude and radius of swing, 14° and 180 cm. The means of opposite lubber-line readings, however, give the same deviation. Just to what extent this sliding motion can be taken into account for observations already

made, in which simultaneous readings were not made on opposite parts of the card, is yet to be investigated.

It might be possible to design the form of bearing-surface so as to eliminate or reduce the sliding motion. Suggestions on this question are deferred pending a macroscopic examination of the cap and pivot of the compass used in the experiments, which, however, should not be disturbed until all interrelated experiments have been completed. It might be noted that the collimating-compass readings are probably quite free of effects due to this sliding motion.

A maple-wood track has been installed in connection with the automatic swing used to record photographically dynamic deviations of compasses under test at Washington. This assures a more constant amplitude of the swing as the experiments pass from heading to heading. The record is made with a motion-picture camera. The readings of the films are facilitated by using an ordinary dissecting microscope stand, which gives a view of several exposures together. The particular exposures required for measurements by means of optical projections can then be selected before the reel of film is put in the projecting apparatus, thus avoiding many unnecessary readings.

Geographical distribution of sudden commencements. W. J. Peters.

A study of the geographical distribution of sudden commencements which had been deferred¹ pending the construction of the apparatus for reducing magnetograms to one common scale² was resumed. Twenty-seven observatories, including our own, broadly scattered over the world, had been selected to furnish magnetograms covering the beginning of magnetic storms of January 29, 1924, March 29, 1924, March 5, 1926, January 24, 1927, May 27, 1927, and October 18, 1928. Upon receipt of all the magnetograms it was found that the characteristic feature of the sudden commencement was poorly defined on many magnetograms for March 29, 1924. This storm has been omitted for the present and replaced by that of September 21, 1925, which had been studied in an earlier investigation.

As usual, the sudden commencements are more conspicuous in curves of horizontal intensity, H , and the preliminary indication, "kick," lasting about one minute or less, and showing a decrease in H is quite marked in some magnetograms while absent in others. The "kick" when present and the next change, the latter very much larger in the opposite direction and lasting 2, 3, or 4 minutes, have both been scaled for this investigation. These have been designated by ΔH , and the corresponding changes in the other elements by ΔD , ΔZ , or ΔX , ΔY , ΔZ for magnetographs registering these elements. Although ΔH is usually positive for the larger change, it is not always so, as may be seen in the magnetograms of Sodankylä and Pavlovsk for September 21, 1925. Values of ΔX , ΔY have been computed from ΔH and ΔD ; also $R = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$ for each observatory. They are tabulated in the interest of other investigations. The directions of R in space referred to astronomical coordinates have been computed for stereographic projection and will be used in the constructing of stereograms showing the magnitude and direction of R on a transparent globe representing the Earth.

¹ Carnegie Inst. Wash. Year Book No. 30, 1930-31, 285 (1931).

² Carnegie Inst. Wash. Year Book No. 30, 1930-31, 286 and 358 (1931).

Radium content of ocean-bottom sediments. C. S. Piggot. *Amer. Jour. Sci.*, vol. 25, 229-238 (Mar. 1933).

Mesures de la resistivité de la Terre et leur application à la géophysique et aux problèmes techniques. W. J. Rooney. *C. R., Cong. Internat. d'Electricité*, Paris, vol. 12, 275-290 (1932).

The significance and accuracy of measurements of earth-current potentials. W. J. Rooney. *Terr. Mag.*, vol. 37, 363-374 (Sept. 1932).

Diurnal variation of earth-current potentials on magnetically disturbed and magnetically calm days. W. J. Rooney.

The comparison of the diurnal variation of earth-current potentials on days designated as internationally disturbed and calm magnetically, previously made using the records from Watheroo and Ebro¹, has been extended by a study of the records for two years from Huancayo. The Huancayo records previous to 1930 were not sufficiently complete for this purpose; hence the comparison is based on the data for the years 1930 and 1931. Again a small but distinct and fairly consistent difference in diurnal variation between disturbed and calm days is found. The disturbed-day diurnal-variation curves are displaced somewhat toward the south and east, respectively, during the hours centering on noon and toward the north and west during the other half of the day. This has the effect of accentuating the northward minimum (or southward maximum) and the eastward maximum which are found in the normal diurnal-variation curves shortly after noon,² and of decreasing proportionally the northward maximum and eastward minimum which occur simultaneously in the forenoon. The difference-curve, like that for Watheroo, is essentially a single-period curve, but appears to have a somewhat smaller relative amplitude and a phase-difference of about 90° from that obtained from the Watheroo records. The diurnal-variation curves for the individual months are much less consistent in the differences they show than were similar records from Watheroo, probably because the number of days included in a given curve is ten or less.

A preliminary study has also been made of the data from Tucson, where recording was begun during the first half of 1931. The period covered by the comparison runs from July 1, 1931, to June 30, 1932. There the disturbed-day diurnal-variation curves differ from those for calm days by about the same amount as at Watheroo and Ebro, but the difference-curve for this one-year period is not smooth enough to bring out the details of the differences definitely. A single-period difference-curve is strongly suggested, however.

A notable feature of the comparisons made using the data from all four observatories is that the disturbances apparently affect only the amplitude of variation and do not materially change the direction of current-flow.

Earth-current measurements at the College-Fairbanks Polar Year Station. W. J. Rooney and K. L. Sherman.

Continuous recording of earth-current potentials was begun in September 1931 at the College-Fairbanks (Alaska) Polar Year Station and will be continued certainly throughout the remainder of the International Polar Year and probably also throughout the coming winter. The potentials measured are those between two pairs of electrodes, one pair 1.28 km. apart on a due south-north line and the other 1.21 km. apart on a due west-east line. The electrodes are grids of lead which were buried at depths of about one meter. The measuring apparatus consists of two Leeds and Northrup

¹ Carnegie Inst. Wash. Year Book No. 31, 1930-31. 270 (1932).

² *Terr. Mag.*, vol. 35, 213-224 (Dec. 1930).

type-R galvanometers and a la Cour photographic recorder. The current sensitivity of the galvanometers, about 1×10^{-10} amperes per mm. deflection on the drum, is such as to permit the use of resistances of 2.0 megohms in series with them so that the total resistance of the circuits is not appreciably affected by variations in line-resistances and in the contact-resistances of the electrodes. The total external resistance of the circuits was less than 300 ohms on either line at the time of installation, and although it has increased considerably during the winter months due to increased contact-resistance at the electrodes as the soil about them froze, it never reached as much as one per cent of the total circuit-resistance in the case of the west-east line or as much as three per cent in the south-north line.

To date the records for the first three full months' operation have been reduced. The most striking features of the records are the comparatively great short-period fluctuations occurring almost exclusively at night and the contrasting smoothness of the traces during the daylight hours. The amplitude of these short-period oscillations frequently reaches one volt per km. or more. Comparison with the auroral log of the station shows a very close correlation between auroral displays and these night-time fluctuations, and the correlation with magnetic disturbances is also good.

The mean diurnal-variation curve for the northward component during the three-month period (October to December) shows a fairly smooth double oscillation in potential gradient with maxima at 4^h and 16^h local time and minima at 11^h and about midnight. The range of variation in the hourly mean values is a little over 12 mv/km. The corresponding curve for the eastward component is also of double period, almost opposite in phase to the northward component, with minima at 5^h and 17^h and maxima near noon and midnight. Its mean diurnal range is about 7.7 mv/km. The phase-opposition of the two components as shown in the diurnal variation agrees with the indications given by the short-period disturbances, during which a westward deflection invariably accompanies a northward one, and an eastward, a southward swing.

The mean diurnal-variation curves for the ten least disturbed days per month (30 days in all for the three months) agree well with the curves for all days during the daylight-hours, but show much smaller amplitudes and less fluctuation during the night.

The magnitude of the potentials recorded showing, as they do, a range of diurnal variation of 13 or 14 mv/km. for the resultant and short-period fluctuations with amplitudes greater than 1 volt/km. may appear at first glance to be abnormally great for a polar station. It should be borne in mind, however, that the average resistivity of the region, with its permanently frozen subsoil, may well be more than one hundred times as great as that of the usual non-polar station. Hence the recorded potentials do not represent greater current-densities here but actually comparatively minute ones.

OA4U—On the roof of the world. S. L. Seaton. Q S T, vol. 17, 9, 31 (July 1933).

The diurnal variation in air-potentials at College, Alaska, October 1932 to March 1933. K. L. Sherman.

The air-potential registrations for the first six months of operation at the College-Fairbanks Polar Year Station have been reduced and charted. The graphs show a very sharp principal maximum at about 8^h, 150° west mean time. There is also a tendency in most of the curves for two secondary maxima, one at 2^h and the other at 19^h, 150° west mean time. The mean values for the months are: October 104, November 112, December 112,

January 135, February 113, and March 114, all in volts per meter using a tentative reduction-factor of 1.10. One conspicuous feature during this period was the infrequent occurrence of negative potentials.

Note on the practical correction of deep-sea reversing-thermometers and the determination of the depth of reversal from protected and unprotected thermometers. F. M. Soule. *Hydrogr. Rev.*, vol. 10, 126-130 (May 1933).

Echo-sounding on the arctic submarine *Nautilus*. F. M. Soule. *Mass. Inst. Tech.*, and Woods Hole Oceanogr. Inst., *Papers Phys. Oceanogr. Met.*, vol. 2, No. 1, 65-76 (1933).

Sounding-velocities in the Pacific. F. M. Soule. [Prepared for the Fifth Pacific Science Congress, June 1933.]

Scientific results of the *Nautilus* expedition, 1931. I: Introduction and narrative. II: Oceanography. H. U. Sverdrup. *Mass. Inst. Tech.*, and Woods Hole Oceanogr. Inst., *Papers Phys. Oceanogr. Met.*, vol. 2, No. 1, 2-63 (1933).

Vereinfachtes Verfahren zur Berechnung der Druck- und Massenverteilung im Meere. H. U. Sverdrup. *Geofys. Pub.*, vol. 10, No. 1, 1-9 (1933). [Pub. Chr. Michelsens Inst., No. 26.]

Geofysiske undersøkelser, særlig over vindens betydning for havstrømmene. H. U. Sverdrup. *Bergen, Chr. Michelsens Inst., Beretninger III*, 5, 1-25 (1933).

Physical and chemical problems of Pacific oceanography: The circulation of the Pacific. H. U. Sverdrup. [Prepared for the Fifth Pacific Science Congress, June 1933.]

Intertropical atmospheric circulation over the Pacific as based on the observations of the *Carnegie*. A. Thomson. [Prepared for the Fifth Pacific Science Congress, June 1933.]

Measurements of total and uncharged nuclei and large ions in the free atmosphere at Washington, D. C. O. W. Torreson and G. R. Wait.

In July and August 1931, observations were made on the total and uncharged condensation-nuclei in the free atmosphere on the grounds of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, in northwest Washington. The nuclei were measured before and after passing through a large-ion counter between the tubes of which sufficient potential was applied (about 900 volts) to remove all charged nuclei with mobility of $1/3000$ cm. per second per volt per cm. From 21 sets of measurements the ratio of uncharged to total nuclei (N_0/N_A) is found to be 0.72, the mean value of N_0 being 7200 and of N_A 10,000. With potentials of 535 and 1890 volts on the large-ion tubes, practically no change occurred in N_0/N_A , showing the mobility to be not less than $1/1700$ cm. per second per volt per cm.

In October and November 1931, 77 measurements were made with the large-ion counter on the number of electronic charges of one sign (positive and negative alternately) per c.c. in the atmosphere, simultaneously with measurements of total and uncharged nuclei. Small ions were removed from the air entering the large-ion counter by a small-ion counter attached at the intake. From these data N_0/N_A is again 0.72, N_{\pm}/N_A is 0.14, N_0/N_{\pm} is 5.8, and the charge per large ion 1.10, the last figure being in good support of the generally accepted view that each large ion carries only one electronic charge. It is seen that $N_A = N_0 + 2N_{\pm}$. The values of N_0 and N_A are more than double those found in July and August, being 15,000 and 21,000 nuclei per c.c., respectively. These results are compared with the work of J. J. and P. J. Nolan, Scholz, Hess, and Israël, and some evidence is found for believing that the ratio N_0/N_A increases in magnitude with increasing nuclei-content of the air.

A quite different analysis of the data obtained in October and November than was made for the above results is undertaken on the basis that N_{\pm}/N_A is not 0.14 but has instead two values, since 23 individual values fall closely

around 0.20 and the remaining 54 around 0.10. The immediate conclusion is that the nuclei are at times doubly charged. From this point of view, the data are retabulated and re-examined and it is found that the results do not show any inconsistencies which would preclude the possibility that doubly charged large ions were present almost exclusively on certain occasions and singly charged almost exclusively on other occasions during the observations here discussed.

- Recherches expérimentales sur les tubes à vide à très hautes tensions. M. A. Tuve. C. R., Cong. Internat. d'Electricité, Paris, vol. 2, 916-929 (1932).
- Recent advances in nuclear physics. M. A. Tuve. [Presented at a Colloquium on Nuclear Physics, New England Section, American Physical Society, Cambridge, Massachusetts, Feb. 4, 1933.]
- Search by deflection-experiments for the Dirac isolated magnetic pole. M. A. Tuve. Phys. Rev., vol. 43, 770-771 (May 1, 1933).
- The atomic nucleus and high voltages. M. A. Tuve. Jour. Frank. Inst., vol. 216, 1-38 (July 1933). [Franklin Institute lecture, Philadelphia, Pennsylvania, Feb. 2, 1933.]
- High-voltage work at the Department of Terrestrial Magnetism. M. A. Tuve. [Presented at the Physics Colloquium, University of Michigan, Aug. 9, 1932.]
- Basic investigations in atomic and nuclear physics at the Department of Terrestrial Magnetism. M. A. Tuve. [Prepared for the conference held at the Institution, Oct. 7 and 8, 1932.]
- The search for an understanding of magnetism. M. A. Tuve. [Presented at Carnegie Institution of Washington, Washington, D. C., Dec. 11, 1932.]
- Nuclear disintegration. M. A. Tuve. [Presented at the Physics Colloquium, Princeton University, Princeton, New Jersey, Feb. 6, 1933.]
- Disintegration-experiments on elements of medium atomic number. M. A. Tuve. [Presented at a Symposium on Nuclear Disintegration, American Physical Society, Chicago, Illinois, June 23, 1933.]
- Super-voltage radiations. M. A. Tuve. [Presented at Symposium on Chemistry and Physics in Cancer, Johns Hopkins University, Baltimore, Maryland, June 29, 1933.]
- Nuclear-physics experiments at the Department of Terrestrial Magnetism. M. A. Tuve and L. R. Hafstad. [Presented before Philosophical Society of Washington, Washington, D. C., Mar. 25, 1933.]
- Disintegration-experiments on elements of medium atomic number. M. A. Tuve, L. R. Hafstad, and O. Dahl. Phys. Rev., vol. 43, 942 (June 1, 1933).
- Nuclear-physics studies using the Van de Graaff electrostatic generator. M. A. Tuve, L. R. Hafstad, and O. Dahl. (Abstract) Phys. Rev., vol. 43, 1055 (June 15, 1933). [Presented before American Physical Society, Washington, D. C., Apr. 29, 1933.]
- Synoptic weather reports in the South Pacific Ocean. J. Wadsworth. London, Q. J. R. Met. Soc., vol. 58, 464-466 (Oct. 1932).
- Apia Observatory—Annual report for 1930. (J. Wadsworth.) Wellington, N. Z., Dept. Sci. Indust. Res., 71 (1932).
- Apia Observatory—Annual report for 1931. (J. Wadsworth.) Wellington, N. Z., Dept. Sci. Indust. Res., 96 (1933).
- Terrestrial Magnetism in Samoa. J. Wadsworth. [Prepared for the Fifth Pacific Science Congress, June 1933.]
- Atmospheric electricity in Samoa. J. Wadsworth. [Prepared for the Fifth Pacific Science Congress, June 1933.]
- The Aitken pocket nuclei-counter. G. R. Wait. Beitr. Geophysik, vol. 37, 429-439 (1932).
- Das anomale Verhalten der magnetischen Permeabilität des Eisens in hochfrequenten Feldern. G. R. Wait. Zs. Physik, vol. 77, 695-698 (1932).
- Weitere Bemerkungen über das Nicht-Vorhandensein einer Permeabilitätsanomalie des Eisens innerhalb des Wellenlängengebietes von 84 bis 1300 m. G. R. Wait. Zs. Physik, vol. 83, 786-788 (1933).
- Variations in the small-ion content of the atmosphere and their causes. G. R. Wait.

A review of the small-ion content data from ocean areas, obtained aboard the *Carnegie*, and of the electrical conductivity of the atmosphere measured

at the various observatories of the Department of Terrestrial Magnetism, shows that, contrary to the expressed opinion of some writers, the number of small ions in the atmosphere is not necessarily greater during the day than during the night, nor everywhere greater during the summer than during the winter. Evidence is presented in support of the generally accepted theory that the number of ions in the atmosphere at a given place and at a given time depends not so much upon the time of day, nor the time of year, as upon the two factors, namely, rate of production and the rate of removal by charged and uncharged nuclei.

Atmospheric ionization. G. R. Wait and A. G. McNish.

A program of observations to ascertain the variation in the rate of ionization in the atmosphere has been in progress at the Department of Terrestrial Magnetism since January 1933. The apparatus used in this work consists of a 25,000-c.c. closed hollow cylinder of a large-mesh brass-wire screen covered with thin cellophane (stopping-power for alpha-particles equivalent to from 1 to 2 cm. of air). Through the center of the cylinder passes an insulated brass rod, which is connected electrically to the fiber of a single-fiber Wulf electrometer. A saturation-potential is maintained between the wire screen and brass rod so that the generation of ions inside the cylinder results in an accumulation of charge on the electrometer fiber system. The rate of accumulation of charge and also the electrometer-calibration made once per hour are photographically recorded on sensitized paper.

Variations in the mean daily rate of ion-formation within the cylinder are as great as twofold. This rate of ion-formation includes the residual ionization within the cylinder; therefore, that due to radiations from ground and air must be even greater than this. Tests made by shielding the chamber indicate that all but a negligible portion of the ionization is due to radiations more penetrating than alpha-particles. There are indications of a regular diurnal-variation in the rate of ionization, but the reduction of the data has not been carried sufficiently far to completely establish its character. One conspicuous observed phenomenon is an increase in the apparent rate of ionization by several fold during thunder-storms.

Quelques facteurs affectant la conductibilité électrique de l'atmosphère. G. R. Wait and O. W. Torreson. C. R., Cong. Internat. d'Electricité, Paris, vol. 12, 158-167 (1932).

The reciprocal character of the diurnal variations of large and small ions in the atmosphere. G. R. Wait and O. W. Torreson.

With a continuously recording-apparatus, measurements of the number of large and small ions in the atmosphere were made during January 1933, on the grounds of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, in northwest Washington. The mean large-ion diurnal-variation curve for 14 complete days during the month shows a sharp maximum between 8^h and 9^h, 75° west meridian time, and a broad maximum of about the same amplitude between 18^h and 23^h. The mean small-ion diurnal-variation curve for the same days has a sharp minimum coinciding in time with the sharp morning-maximum of the large-ion curve and a broad minimum occurring at the same time as the broad evening-maximum of the large-ion curve. The principal maximum of the small-ion curve occurs at about noon and a secondary maximum, having about half the amplitude of the principal maximum, at about 4^h. The two minima of the large-ion curve occur at these times. Thus, except for minor details, one curve is a reciprocal of the other. The average count per c.c. given by the small-ion counter and by the large-ion counter, for the 14 days, was 182 and 5200, respectively.

When simultaneous hourly values of small-ion and large-ion content of the atmosphere are plotted for the entire 14 days, a hyperbola is obtained, and consequently there exists a linear relationship between the small-ion content and the reciprocal of the large-ion content. This linear relationship may be expressed by the equation $n_+ = A + B/N_+$, where n_+ represents the number of small positive ions per c.c. as given by the small-ion counter; N_+ represents the number of large positive ions as given by the large-ion counter and A and B are constants. The data appear to fall into two groups of days; the values of A and B are 100 and 48×10^6 , respectively, for one group of days and 92 and 24×10^6 , respectively, for the other group. Considerable significance may be attached to the value of these constants. For example, it is quite likely that the value of the constant A is a measure of the contribution to the current in the small-ion counter by intermediate and large ions. That is, the current due to the intermediate and large ions corresponds to a contribution by 100 small ions for one group of days and by 92 for the other group. Since the average small-ion content as recorded by the small-ion counter for the 14 days was 182, a large percentage of this value must be attributed to other than small ions. The fact that the value of the constant B for one group of days is double that for the other group may possibly signify that one group is made up mostly of singly charged large ions while the other group is made up mostly of doubly charged large ions. Additional evidence pointing to the possibility that large ions may at times have a single electronic charge and at other times two electronic charges has been obtained in previous investigations by the writers.

Comparison of auroral and magnetic activities as recorded at Little America, 1929. W. F. Wallis.

Using the auroral log of June, July and August 1929, of the Byrd Antarctic Expedition, daily and hourly mean values of auroral intensity were derived and compared with corresponding values derived from the magnetic records. It was found that while there was some similarity between the curves representing the diurnal variation of auroral intensity and the diurnal variation of the magnetic disturbing-force, particularly in the north-south direction, in general there did not appear to be a close correspondence between auroral intensity and the intensity of magnetic disturbance. For example, in the largest magnetic disturbance recorded at Little America, that of July 10 and 11, 1929, during the period of maximum magnetic disturbance, lasting for six hours, only slight or moderate auroral activity was recorded. On the other hand, during the same magnetic storm, two brilliant auroral outbursts were accompanied by sudden sharp increases in the magnetic disturbance, while another brilliant auroral outburst was not so accompanied. In regard to the curves representing the daily mean values of auroral and magnetic activities, the highest peaks on the auroral curves sometimes, but not always, found counterparts on the magnetic curves. Another question considered was whether or not there was a relationship between the direction from the point of observation of the brightest portion of an auroral display and the direction of the magnetic disturbing force. A number of particularly brilliant auroral displays were selected and vectors were drawn to represent the direction and intensity of the aurora and also the direction and intensity of the magnetic disturbing-force, but no systematic relationship could be discovered. The conclusion is, therefore, that there is no definite relationship between auroral and magnetic activities. The same conclusion was reached by Chree in his discussion of magnetic disturbances and aurora as recorded on the British Antarctic Expeditions of 1901-04 and 1910-13 and the Australasian Antarctic Expedition of 1912-13.

TORTUGAS LABORATORY¹

W. H. LONGLEY, EXECUTIVE OFFICER

During the season the following investigators worked for the periods and upon the subjects of research indicated:

- Paul Bartsch. U. S. National Museum. Cerion studies. August 9 to 21.
L. R. Cary. Princeton University. Culture of *Ptychodera* tissues *in vitro*.
July 27 to August 21.
H. H. Darby. The Bartol Foundation. Regeneration in Alpheidæ; the pigments of Linuche. May 31 to August 7.
Myron Gordon. Cornell University. The internal pigment systems of fishes. June 14 to July 10.
Caswell Grave. Washington University. Ascidian metamorphosis. June 28 to August 7.
E. R. Helwig. University of Pennsylvania. Regeneration in *Iotrochota birotulata*. June 14 to August 21.
M. J. Kopac. University of California. Physiological studies on *Valonia ventricosa*. May 31 to August 7.
W. H. Longley. Goucher College. Taxonomic and field studies of Teleost fishes. May 31 to August 21.
C. W. Merriam. University of California. Study of modern coral reefs in relation to problems of palæontology. August 9 to 21.
Paul A. Nicoll. Washington University. Assistant to Dr. Grave. Ascidian metamorphosis. June 28 to August 21.
Fernandus Payne. Indiana University. Embryology and cytology of *Ptychodera bahamensis*. June 28 to August 21.
P. B. A. Powers. University of Pennsylvania. Ciliates infesting Tortugas echinoids. June 14 to August 21.
F. C. Steward. University of Leeds. Salt absorption and respiration of *Valonia*. May 31 to August 21.
Geoffrey Tandy. British Museum (Nat. Hist.). Transplant and succession studies on marine algæ. May 31 to August 21.
D. H. Tennent. Bryn Mawr College. Experimental studies in the embryology of echinoids, particularly *Clypeaster rosaceus*. June 28 to August 7.
J. M. Wilson. Medical College of South Carolina, Assistant to Dr. Cary. Culture of *Ptychodera* tissues *in vitro*. July 27 to August 21.
Shigeo Yamanouchi. University of Chicago. Ecology and cytology of marine algæ. May 31 to July 24.

A few of the season's results immediately available and readily summarized may be noted here. For the rest, investigators' individual reports may be consulted.

The value of the photographic method of obtaining an analyzable record of some phases of cellular activity is recognized. Dr. Cary is applying it in his study of regenerating *Ptychodera* tissues.

It has long been known that when the large claw of certain alpheid shrimps is lost, a reversal of symmetry occurs at the succeeding moult. But by modifying experimental conditions, Dr. Darby may obtain regen-

¹ Situated at Tortugas, Florida.

eration without reversal, or may produce forms with two large or two small claws. His experiments exhibit the process of differentiation in a novel aspect and seem to him to give an inkling at least of the nature of the chemical process involved.

Dr. Grave, assisted by Mr. Nicoll, has discovered a number of substances—organic and inorganic and baffling in their diversity—which accelerate metamorphosis in the ascidian tadpole. With these discoveries a real advance in knowledge is made, but the problem of the immediate cause of metamorphosis becomes as difficult of solution as that of the immediate cause of the development of an egg, induced as it is in as great or greater diversity of ways. As an interesting by-product of Dr. Grave's work, it appears that, on account of its visible and speedy response under chemical treatment, the Ascidian larva is an excellent biological indicator available to biochemists and others.

An observation by Dr. Kopak that *Valonia* cells injured by puncture immediately enter upon a process of vegetative reproduction and give shortly small cells of a wide range of sizes and with no vacuoles, or with small or large ones, lays this plant open to experimental study upon new terms.

To study the living coral reef, as Dr. Merriam has done, for the light it throws upon particular palæontological problems, is a variant of the general procedure of reconstructing the past from observation of present conditions. It is to be anticipated that others may with advantage make like use of the Laboratory's facilities.

Dr. Steward's precise and intensive studies in the physiology of *Valonia* appear to necessitate repetition of certain earlier experiments and modification of some of the conclusions drawn from them.

Mr. Tandy's observations upon transplanted algæ demonstrate anew—as H. M. Hall showed earlier for flowering plants—that in taxonomy the ultimate criteria for species are to be found in the behavior of the living organism. It must not be assumed, however, that because experimental tests show so clearly that species, particularly in small collections, can not always be distinguished by morphological criteria alone, that they are not generally distinguishable upon that basis. Still another comment: the alleged or putative species and varieties which Mr. Tandy reduces to synonymy are forms actually existent in nature. All that seemed once to entitle them to recognition as species or varieties now enriches the definition of species of which they are severally recognized as growth forms. The proponent of the idea that species are subjective creations of the taxonomic mind will note the greatly reduced possibility of confusing with one another those species which after experimental testing are still counted good. It is largely the misconception embodied in the taxonomic record which tends to blur the outlines of specific groups objectively existing.

Cerion Studies, by Paul Bartsch

Doctor Bartsch's visit to the Tortugas this year concerned itself chiefly with securing of adequate material for cytological study of *Cerion viaregis*, *Cerion casablancae*, *Cerion incanum* and hybrids of *Cerion viaregis* × *Cerion incanum* and *Cerion casablancae* × *Cerion incanum*, and making

arrangements to have specimens of these sent periodically to Washington in order to get the developmental cycle.

Incidentally, the various colonies on the Tortugas were overhauled and the cages replanted where necessary and a new colony of a mixture of *Cerion viaregis* and *Cerion incanum* was started near the dining-room. This was deemed advisable in order to serve as a check against the happenings on New Found Harbor Key and also to preclude the possibility of having that experiment terminated by fire as has been the case of some of the other colonies.

Arrangements were made with the Keeper of Munson (= New Found Harbor Key) for periodic sendings of specimens, and likewise with the lighthouse keeper at the Tortugas and Mr. Demerit at Key West.

Cytological studies by Professor Paul Bowman and some of his students are well under way and they are showing interesting results.

A series of motion pictures was taken of the sooty and noddy tern colony, more than half of which has now left Bird Key and taken possession of Bush Key and Long Key, as well as Garden Key. It is beginning to look as if the major portion would eventually establish itself on Long Key. However, it was a splendid chance to get this transitional movement recorded on our film.

Two thousand additional feet of film were exposed in taking pictures under sea about the coral reef.

Further Studies on Tissues of Ptychodera bahamensis in vitro, by L. R. Cary

Using the technique described in earlier reports of this series, cultures of caecal endoderm cells of *Ptychodera* were used exclusively for our studies during the present season. While not all explants were prepared with sufficient care to insure the presence of this type of cell only, cells of other types were present in such small numbers that their influence on the behavior of the culture as a whole was negligible.

The routine of preparing cultures and of obtaining a series of cinematographic records of the activities of the caecal endoderm cells was shared by an assistant, Mr. James M. Wilson, of the Medical College of South Carolina, without whose aid many of the results obtained would have been impossible of accomplishment in the limited time at my disposal.

By the use of a microphote and a modified "Sept" camera, series of exposures at ten-second intervals were obtained from several cultures.

The record of the activity of some cultures extended over a period of eight hours. For others only the initial period during which the protoplasmic activity was at its height was recorded.

Altogether, approximately 1000 feet of photographic records were obtained. Some of these illustrate the general activity of the cultures as seen under low-power magnification. By far the greater number were high-power records of small areas, where a relatively few cells were kept under observation for as long as their protoplasmic movements were clearly evident through the viewing lens of the microphote. Even after evident migration had ceased, certain cultures were photographed for a considerable period in order to record any less evident activities.

While all of the films have been developed, and it has been shown that satisfactory records were secured, no attempt has as yet been made to study the nature of the mechanics of cellular movement.

In observing the cultures studied, many records were obtained of the influence of temperature, light intensity and composition of culture medium, on rate and extent of growth and longevity of cultures.

The previous condition of the organisms from which cultures were made, as compared with the resulting cultures, was also carefully checked.

Studies on Regeneration in the Alpheidæ, by H. H. Darby

The classical experiments of Przibram and Wilson were repeated on *Crangon armillatus* and entirely substantiated.

Counts made on the above organism and on *Synalpheus longicarpus* show that right- and left-sided individuals occur in nature in equal numbers irrespective of sex.

The removal of both chelæ with varying intervals of time between them was performed in a search for a time factor in the regenerative process. A definite relationship between the type of chela regenerated and the time interval between the removal of the two chelæ was discovered.

STUDIES ON PIGMENTS OF LINUCHE UNGUICULATA (ESCHSCHOLTZ)

This small medusa has two forms, one during the day, another during the night. The difference lies in the coloration of the umbrella and the localization of the pigment. During the day the lower two-thirds of the umbrella has a diffuse yellowish brown color; at night the former color disappears and a spotted dark-green pattern takes its place.

Two pigments were extracted: the one (A) acetone-soluble only; while the other (B) was soluble in both acetone and alcohol. According to the state of oxidation of these two pigments the day or night form may be obtained. The oxidation seems to be dependent in part on light absorption.

Studies on Pigmentation of Fishes, by Myron Gordon

In addition to their colors externally visible, most fishes possess elaborate internal pigmentary systems discoverable upon dissection. These systems were studied in a number of representatives of the major taxonomic groups. Specimens of *Halichæres bivittatus* and *Lutianus griseus*, showing growths, possibly neoplastic in nature, were also collected for study.

Acceleration of Metamorphosis of Ascidian Larvæ, by Caswell Grave and Paul A. Nicoll

Beginning June 28, experimental studies were made to ascertain what environmental conditions induce or accelerate metamorphosis of larvæ of the ascidians, *Phallusia nigra* and *Polyandrocarpa tinctoria*.

The substances enumerated below, in the order used, were placed in sea-water with swimming larvæ and the effect of each on metamorphosis was noted in comparison with the metamorphosis of larvæ of like parentage, age and number, swimming in an equal volume of fresh sea-water.

SUBSTANCES FOUND TO ACCELERATE METAMORPHOSIS

Sea-water in which *Phallusia* eggs developed and hatched.

Lactic acid.

The precipitate that appears when NaOH is added to sea-water.

The precipitate that appears when KOH is added to sea-water.

BaCl₂ or its precipitate with sea-water.

CO₂-free sea-water.

Thyroid (whole gland) extract.

Phallusia endostlye tissue extract. (This accelerated metamorphosis in *Phallusia* larvæ but not in *Polyandrocarpa* larvæ.)

Phallusia mantle and atrium tissue extract. (This accelerated metamorphosis in *Phallusia* larvæ but not in *Polyandrocarpa*.)

Berkshire-sand solution. (Ground with sea-water in a mortar; the filtrate used.)

Pituitary (whole gland) extract.

Pituitary (anterior lobe) extract.

Polyandrocarpa tissue (whole colony) extract. (This accelerated metamorphosis of *Polyandrocarpa* larvæ but had no accelerating effect on larvæ of *Phallusia*.)

SUBSTANCES THAT EITHER HAD NO ACCELERATING EFFECT OR TENDED TO INHIBIT METAMORPHOSIS

Acetyl coline.

Pituitrin "O."

Adrenalin.

CO₂-saturated sea-water.

Oxygen saturated sea-water.

NaOH when its sea-water precipitate is removed or when no precipitate is formed.

KOH when its sea-water precipitate is removed or when the precipitate has not formed.

HCl.

NaCl.

KCl.

Cynthia tissue (adult) extract. (This has no accelerating effect on larvæ of either *Phallusia* or *Polyandrocarpa*.)

SUBSTANCES FOUND TO BE TOXIC TO LARVÆ

AgNO₃ and its precipitate with sea-water.

Phallusia egg extract.

Phallusia blood.

In this preliminary report only very brief statements of details of experimental methods employed or of results obtained can be made.

The work of P. Weiss (1928), in which thyroid gland extract was shown to accelerate metamorphosis, was repeated but, as is later explained, we do not agree with the conclusion that the accelerating agent is thyroxin.

No evidence was found that changes in pH in larval tissues or in the surrounding medium have an accelerating effect on metamorphosis, as

claimed by N. J. Berrill (1929), but the precipitate produced in sea-water by the addition of NaOH (or KOH) was found to accelerate metamorphosis to a greater extent than any other substance yet tried. Data from experiments made with NaOH will serve to show the effectiveness of this substance:

43 *Polyandrocarpa* larvæ, liberated between 10:40 and 10:48 a.m., August 2, placed immediately in a vial containing 27 c.c. of an NaOH-sea-water medium. (The control vial contained 56 larvæ liberated by the parent between 10:40 and 10:45.) A precipitate appeared in the experimental vial at the time the larvæ were introduced. At 10:50 several larvæ were seen to be attached to the side of the upper part of the vial, their tails in active vibration. At 11:03 and 11:08 larvæ continued to attach to the side of the vial. At 11:20 the tails of many of the attached larvæ had been retracted and at 11:30 all larvæ in the experimental vial had completed their metamorphosis, while none in the control vial had metamorphosed at 2:45 p.m.

In experiments with NaOH and KOH-media in which no precipitate appeared, larvæ metamorphosed no sooner than those in unmodified sea-water; in others in which the appearance of the precipitate was delayed (20 minutes to 2 hours) metamorphosis was delayed to the same extent. In experiments in which the sea-water used had been treated with NaOH or KOH several hours in advance and from which the precipitate had been filtered, metamorphosis occurred no more quickly than in vials containing unmodified sea-water; and in experiments in which the medium was prepared in the same way as in the preceding except that the precipitate remained at the bottom of the vial, metamorphosis was induced as rapidly and as fully as in the experiment first described. In all of these experiments the pH remained practically constant, hence our conclusion that it seems to play no significant rôle in accelerating metamorphosis. Just what the effective agent may be in NaOH or KOH-media is not yet determined, but it must be in some way connected with the precipitate.

Another series of experiments in which various tissue extracts in sea-water were used deserves mention:

When a sea-water solution of a Parke, Davis and Company preparation of thyroid gland extract was found to be an effective accelerator of metamorphosis in the larva of *Phallusia*, the inference that the acceleration is due to thyroxin seemed a natural one, and thus the question was raised whether thyroxin is synthesized in the ascidian endostyle, the supposed homologue of the thyroid gland of vertebrates. When an extract made from the endostyles of 19 *Phallusia* adults (166 mg. ground 15 minutes in 10 c.c. of sea-water, yielding 7.25 c.c. filtrate; placed in two 10 c.c. vials, 4 c.c. in one, 3 c.c. in the other—both brought to the 9 c.c. mark with sea-water) was found to have induced metamorphosis in *Phallusia* larvæ in 2 hours and 50 minutes to the extent of nearly 100 per cent as compared with larvæ in three control vials none of which had metamorphosed, we were enthusiastically certain that the homology of endostyle and thyroid gland is no longer theory only, but fact. Two days later, however, when it was demonstrated that extracts made from mantle tissue and atrial tissue of *Phallusia* are just as potent as endostyle extract in inducing metamorphosis, we ac-

cepted our disappointment and continued with work to find a possible reason why larvæ treated with the tissue juices of their parents have their swimming life so greatly shortened. Further experiments showed that extracts made from tissues taken from a species of snail and from a species of ascidian, *Cynthia*, have no accelerating effect on metamorphosis of larvæ of either *Phallusia* or *Polyandrocarpa*. This result led to the demonstration that *Phallusia* tissue extract will greatly accelerate metamorphosis of *Phallusia* larvæ, but will have no accelerating effect upon larvæ of *Polyandrocarpa* and vice versa; *Polyandrocarpa* tissue extract greatly accelerates metamorphosis of *Polyandrocarpa* larvæ but has no accelerating effect on larvæ of *Phallusia*.

The seeming unrelatedness of the several substances that have been found to induce metamorphosis and their seeming unrelatedness to any specific link in any conceivable chain of physiological events in the ascidian larva calls for some comment. In the mechanism of metamorphosis we may be dealing with a system such as that involved in the initiation of development in the egg. This mechanism, we know from the work of Loeb and many others, may be activated by many very diverse agencies, of which the sperm is but one—butyric acid, various chemical substances and mechanical stimuli. Except the sperm, none of these agencies seem to have any natural relation to the mechanism of development, yet are effective in its activation. The mechanism of metamorphosis like that of development seems to be subject to activation by any stimulus capable of disturbing the equilibrium of its events and forces.

Regeneration in Iotrochota birotulata (Porifera), by Edwin R. Helwig

Cross-sections, from 2 to 3 mm. thick, were made of the branches of *Iotrochota birotulata*, as in this way all types of cells present in the sponge can be obtained. These sections were folded in bolting cloth (number 20) and gently squeezed until the cells, accompanied by mucus, were forced through the cloth. The cells were allowed to settle directly on to slides immersed in bowls of sea-water.

FORMATION OF AGGREGATES

When the cells are squeezed into sea-water, they lose their characteristic form and become globular. Upon coming in contact with the surface of the slides, all of the cells, except the choanocytes, put out pseudopodia and move about. At first the cells are scattered evenly in a thin film over the slides, but the movement of the cells soon transforms this film into an irregular net. The cells continue to coalesce, so that the strands or meshes of the net break at various places and each section usually contracts into a ball. These balls of cells may continue to move and when they come in contact with one another they fuse. The small aggregates often continue to move after the large ones have stopped, so that the size of an aggregate may determine, in part, how long it will continue to move. However, in 18 hours all movement has ceased, regardless of the size of the aggregate. Only those masses which have not attained a size greater than approximately 0.5 mm. undergo any subsequent development. Without exception, the large aggregates perish without any sign of further development.

DEVELOPMENT OF A NEW SPONGE

Development of a new sponge begins immediately after the formation of the aggregate and is characterized by a spreading of the mass over the substratum. Some of the cells slowly migrate from the periphery of the mass so that the two-day old aggregate is somewhat flattened and surrounded by a thin film of cells. Frequently the cells will spread in two opposite directions rather than from the perimeter. This spreading may continue until the aggregate is completely transformed into a thin film or sheet of cells. More often a central area remains relatively unaffected by this process. A certain amount of spreading seems to be necessary for further development of the aggregate, as otherwise it may continue to live for days or weeks without any sign of differentiation. Eventually the spreading ceases and pores appear on the surface of the aggregate; usually they are found in regions where the mass of the aggregate is greatest.

As soon as the cells begin to migrate from the perimeter, it can be seen that the outermost ones are invariably preceded by a rim of hyaline substance which is secreted by the cells themselves. Meanwhile, changes are occurring within the mass: the cells elongate and eventually become separated into a very loosely knit mass of cells or syncytium. The cells on the surface, however, maintain their intimate connection and thus form a continuous epidermal membrane.

In three or four days, flagellated chambers begin to appear in great abundance in the thicker portions of the aggregate. Canals and pores also develop at this time, but these do not appear at first to have any relation to the developing flagellated chambers.

The microscleres are the first skeletal elements to be formed and these develop throughout the mass without any apparent arrangement. Simultaneously, some of the cells are becoming grouped into cords or strands, usually parallel to the long axis of the mass or, in the case of circular aggregates, into rings. Somewhat later, strands connecting the rings or parallel strands develop. The macroscleres are formed in these cords or strands of cells so that eventually the fibers packed with spicules, which are characteristic of the adult sponge, are formed.

CELLULAR CONSTITUENTS

A suspension of *Iotrochota* cells contains four types. The most conspicuous of these are the archeocytes with mahogany-red spherules. All of the spherules are approximately of the same size. The number of spherules in a cell is usually proportional to its size, but some cells are so full of them that they bulge from the surface. These archeocytes vary in size from 5 to 14 μ , although the majority of them measure 10 μ . The nucleus is obscured in the living cell by the spherules. After fixation, these cells have a highly vacuolated appearance, due to the dissolution of the spherules. The nuclei are small (1 to 2 μ) and usually crenate, the latter characteristic being due to the pressure exerted by the spherules when the cell is full of them.

Another type of archeocyte contains pale-green spherules which vary greatly in size within a single cell, the largest spherules being equal in size to the red spherules found in the preceding type of archeocyte. In addition to these spherules, small red granules are often present, but these appear

to occur in an inverse ratio to the number of spherules, as all stages between cells with granules only and those with spherules only are found. These cells vary in size from 6 to 10μ and the nuclei from 3 to 4μ . The spherules and granules in these archeocytes are fixed in fluids that contain osmic acid.

The distinction between the cells with red spherules and those with pale-green is not definite, as cells which contain both kinds of spherules simultaneously are frequently found.

Another type of cells which contain emerald-green spherules is found only on the surface of the sponge. All the spherules are approximately of the same size and slightly smaller than the red spherules described above. These cells are so full of spherules that they have the appearance of a green mulberry. The nucleus is entirely obscured in the living cells, but after fixation it is found to be small and crenate. The spherules are preserved in any fixative that was used.

The choanocytes are sometimes very abundant in the cell suspensions and at other times none can be found. After being squeezed through the bolting-cloth, they invariably lose their collars but the flagella were usually present and continued to vibrate for two or three hours. The body of the choanocyte is slender and tapering at its proximal end. The distal end is swollen and contains the nucleus. The flagellum is about three times the length of the cell body and is continuous with an intracellular rod which extends to the base of the cell. The cytoplasm is hyaline and free of granules. The choanocytes never exhibit amœboid movement.

The various types of cells can be distinguished after fixation and their rôle in the regeneration of a new sponge is the especial interest of the writer.

Physiological Studies on Valonia ventricosa, by M. J. Kopac

Valonia ventricosa was abundant on Bird Key reef and also on Long-Bush Key reef. Specimens of *V. ventricosa* up to 5 cm. in diameter were collected at infrequent intervals on the seaward side of Long-Bush Key reef. *V. macrophysa*, although fairly abundant in the moat of Fort Jefferson, was not used in these studies.

An experimental study on the production of aplanospores¹ in *V. ventricosa* was made. It was found that if a normal cœnocyte is punctured with a glass or quartz capillary tube over 1 mm. in external diameter, a series of processes is initiated which results in the production of minute spheroidal bodies, the aplanospores. Immediately after the cœnocyte is punctured, the chloroplasts become scattered in the region of the injury. A few minutes later, exceedingly small vacuoles are produced near this region and gradually this formation of vacuoles spreads over the entire protoplasmic layer of the cœnocyte. These vacuoles increase in size and most of them coalesce to produce a very dense reticulum, which eventually spreads over the entire protoplasmic layer. Later there is a separation of this protoplasmic reticulum into many discrete irregular blobs. All of the chloroplasts are contained in these blobs of protoplasm. Within 1 to 6 hours these irregular blobs become spheroidal, and shortly afterward these spheroids become surrounded by a delicate cell wall. While within the cœnocyst,

¹ Setchell, W. A., Personal communication, June 27, 1933.

rhizoidal processes are produced by the spheroids and if left within the cœnocyst a small amount of growth of the spheroids and rhizoids will take place. Quite frequently some of the larger spheroids will divide to form smaller bodies. The average diameter of a spheroidal body with its cell wall is about 100μ .

If these spheroids are removed from the cœnocyst and placed in sea-water, growth takes place and miniature *Valonia* cells are produced. A large number of these small *Valonia* cells grew to a size 1 mm. in diameter within a period of 8 weeks. When these living cells were examined with an Ultropaque illuminator, no central vacuole was seen in the smallest cells, but in the larger cells a very definite and quite frequently a large central vacuole was seen.

A considerable amount of this material was fixed in Bouin's and other fixatives and the cytology of these cells will be studied in the future. The use of these tiny *Valonia* cells in physiological work is suggested. The cell wall is easily penetrated by a micropipette, thus permitting a study of pH and redox potential of the vacuole and the protoplasm by the indicator method. The spherical shape of these cells will permit a study of the rate of swelling of plasmolyzed cells in hypotonic solutions similar to the studies already made by various investigators on marine invertebrate ova.

An important point needs to be emphasized as a result of this experimental study. A perfectly normal and uninjured cœnocyte will never show a scattering of chloroplasts or the formation of vacuoles when examined with a microscope. Under normal conditions the chloroplasts are very uniformly distributed. Just as soon as the protoplasm is injured, there is a scattering of chloroplasts which may be accompanied by the formation of vacuoles. If the wall of the cœnocyte is punctured with a micropipette there is a certain amount of scattering of the chloroplasts and a tendency of the protoplasm to pull away from the micropipette; but if care is taken to insert the micropipette carefully into the cœnocyte, vacuoles are never formed and the protoplasm will heal around the micropipette. Micropipettes as large as 100μ in diameter may be inserted into the cœnocyte without causing the formation of vacuoles.

The changes in electrical resistance during the first few minutes following the insertion of a micro-salt-bridge¹ into the vacuole of the cœnocyte of *Valonia* were studied. Cœnocytes 3 to 5 mm. in diameter and selected on the basis of a uniform distribution of the chloroplasts were used in these experiments. A cœnocyte was placed in a watch-glass filled with fresh filtered sea-water. The watch-glass was then placed on the stage of a binocular microscope previously mounted on the base of a modified Taylor micro-manipulator. A saturated calomel half cell was held by one unit of the micromanipulator and leading from the half cell was a quartz micro-salt-bridge between 25 and 50μ in diameter. This micro-salt-bridge was filled with natural or artificial cell sap. Since the micro-salt-bridge was combined with a Luer syringe, it was possible to inject cell sap into the vacuole of the cœnocyte. In this way a continuity between the cell sap in the micro-salt-bridge and the cell sap in the vacuole was obtained. (A description of this

¹ L. R. Blinks, Jour. Gen. Physiol., vol. 14, 139, 1930.

electrode system will be published shortly.) A duplicate half cell was held by another unit of the micromanipulator, and leading from this was a relatively large salt-bridge filled with saturated KCl-agar. A direct-current Wheatstone bridge with a sensitivity of 0.1 per cent was used to measure the resistance. No polarization of the electrodes was detected at the current density used (0.1 to 1 microampere).

With the cœnocyte submersed in sea-water, the micro-salt-bridge was inserted into the vacuole of the cœnocyte by means of the micromanipulator. Little or no cell sap escaped from the cœnocyte. The other salt-bridge was immersed in the sea-water contained in the watch-glass. The resistance of this system, electrode/ cell sap/ protoplasm/ cell wall/ sea-water/ electrode was measured as soon as the micro-salt-bridge was inserted into the cœnocyte. Then at minute intervals, the resistance of this system was again measured. From the total resistance of this system, the basal resistance of the system, electrode/ cell sap/ sea-water/ electrode was subtracted and the net resistance was then calculated in percentage of the basal resistance. The net resistance was attributed to the protoplasm and cell wall of the cœnocyte. In most cases the total resistance during the first few minutes of the experiment is the same as the basal resistance. However, in from 2 to 5 minutes the net resistance (or resistance due to protoplasm and cell wall) increased to 3 to 7 per cent of the basal resistance, a steady value being obtained about 10 to 12 minutes after the start of the experiment. This increase in resistance is interpreted as denoting the time at which an electrical seal is formed.¹

It is interesting to note that if the cœnocyte is not totally submerged in sea-water and if the micro-salt-bridge is inserted into the exposed portion of the cœnocyte, the net resistance is always 4 to 12 per cent of the basal resistance at the start of the experiment. In a few cœnocytes this net resistance remains constant for 15 to 30 minutes (duration of experiment) and in others there is a slight decrease of resistance with time. In no case, however, was the total resistance equal to the basal resistance at the start of the experiment.

In the submersed cœnocyte there is an electrical leak whereby the current flows from the micro-salt-bridge through the opening in the cell wall to the sea-water and the other salt-bridge. Only when the protoplasm heals around the micro-salt-bridge (the opening in the cell wall being filled with protoplasm) is there an increase in resistance. Cœnocytes injured by the insertion of a micropipette usually demonstrated the formation of a protoplasmic ring around the capillary 5 to 10 minutes later.

This study shows the close relationship between the increase in electrical resistance with time of an impaled *Valonia* cœnocyte and the healing or recovery of the cœnocyte from the injury. This study indicates the desirability of observing morphological changes (microscopically) along with the measurement of experimental factors. In many cases the changes in physical or chemical behavior of an organism may be more clearly interpreted when the accompanying morphological changes (scattering of chloroplasts, vacuole formation, healing, etc.) are known.

¹ W. J. V. Osterhout, E. B. Damon, and A. G. Jacques, Jour. Gen. Physiol., vol 11, 193, 1927.

A Leitz compound binocular microscope, a modified Taylor micromanipulator and various electrical instruments were generously provided by the Department of Zoology, University of California. The use of a Chambers' micromanipulator was made possible through the kindness of Mr. Alfred Traeger of E. Leitz, Inc.

Taxonomic and Field Studies of Teleost Fishes, by W. H. Longley

As part of a project elsewhere reported upon in this issue of the Year Book, my time during the season was given chiefly to checking and organizing observations of previous years. Dredging, however, undertaken in the interest of other investigators, added some fifteen species to those locally known. These included two of the lesser Serranidæ, which as might be anticipated are functionally hermaphroditic.

Study of Modern Coral Reefs in Relation to Problems of Palæontology, by Charles W. Merriam

Reef corals and their ecologic associates are beyond question important contributors of calcareous material toward the building up of many great limestone masses. Consideration of the origin of these deposits leads into problems of biologic, geologic and physico-chemical character, no one of which may well be treated in itself alone. With a view to integration of the evidence derived through these various interrelated lines of approach, it seems reasonable that study of such sediments be undertaken by investigators possessing at once intimate knowledge of biotic conditions upon developing reefs and of the geologic processes there at work. The Dry Tortugas Atoll provides an unusually instructive field for objective study with reference to this subject. Here in the making is a composite limestone body essentially the same as the Floridian Key Largo limestone of Pleistocene age.

Work carried on at Tortugas by Alexander Agassiz, Vaughan and others affords a fund of recorded information, the value of which is supplemented and enhanced by actual observation both from the surface and from beneath the water with a diving helmet.

It is interesting to note the small amount of molluscan life actually observable about the coral growths. These organisms, present no doubt in great abundance, are effectively hidden in caverns and borings within the coral heads or have burrows in unconsolidated débris. Many are hidden by the gorgonians, or like the sessile Chamas are cemented to and form a part of the hard bottom in the *Orbicella* facies, which surface is composed largely of broken and cemented dead coral material. The actual profusion of mollusca about the atoll as a whole is attested by the large percentage of their fragmented shells in sand composing the exposed area of Loggerhead Key and that dredged in shallow water nearby. Study of sediment samples collected will probably supply additional data regarding the relative importance of different classes of lime-secreting organisms in contribution of débris.

In the wave-activating prevalent easterly winds, the Florida counter-current and the tides ebbing and flowing between the keys, one sees in

operation vigorous agencies of sediment transportation, comminution and sorting. A resultant continuous shifting of terminal portions of the keys and of uncemented detrital banks in shallow water is particularly apparent. Disturbance of the waters by more powerful storm winds is very effective in destruction and scattering of gorgonians and of the fragile branching *Acropora* growths. Loose fragments of dead *Acropora* are widely dispersed upon submerged slopes of Loggerhead Key. Pieces of recently destroyed colonies of this coral immediately east of the key appear to be living and may possibly give rise to new growths.

Examination of the cavernous interiors of large *Orbicella* heads is of interest, not alone by reason of the ecologic associates of the coral found there, but because it reveals the structural weakness of many such bodies, some of which must ultimately succumb to destructive forces of heavy storm wave-attack.

Work now in progress on Lower Pliocene faunas from the vicinity of Carrizo Creek, southwest of Salton Sea in California, has brought to light additional molluscan species showing affinity to Floridian and West Indian Pliocene to Recent forms. The reef corals of this supposed former northward extension of the Gulf of California were earlier recognized by Vaughan to be of Atlantic type. Rapid terrigenous sedimentation in the Carrizo Creek region prevented formation of more than an incipient reef, presumably of the fringing type. It may be inferred, however, that conditions as regards water temperature, depth and plankton food supply were much as they are today on the Florida reefs.

Environments favoring growth of reef corals have exerted strong influence in the development of much of our marine rock sequence. Crustal movements and other dynamic agencies affecting Recent coral reefs have acted more or less locally to maintain suitable conditions for continued upward accretion of the corals and appear to have resulted in production of the rarer types of coral reef structures, or so-called "true coral reefs." In many cases fossil reef-corals constitute laterally extensive beds or isolated lens-like bodies, neither being of any great thickness. Whereas here the environmental conditions were temporarily suitable for active growth, renewal or increased rate of clastic sedimentation brought about choking-off and burial of the growing bed or lens while it was yet a thin accumulation.

Though reef-building corals of the later Paleozoic are for the most part members of the extinct *Tetracoralla*, *Tabulata* and *Stromatoporoidea*, they, with little doubt, have ecologic analogues among genera now living about southern Florida. It is hoped that familiarity with conditions on a living reef will promote an insight which will aid in study of Devonian limestones and coralline deposits now being undertaken in western North America.

*Studies on the Embryology and Cytology of Ptychodera bahamensis, by
Fernandus Payne*

My major work centered about *Ptychodera bahamensis*, one of the balanoglossids, and a supposed protochordate; the supposition, however, has always been debatable and still is. During the past several years,

cytologists have described in cells of many animals a substance called the Golgi substance or Golgi bodies. This substance takes a different form in the vertebrates and the invertebrates. It occurred to me that it would be interesting to know whether this substance conformed to the vertebrate or the invertebrate type, and I hope a study of my material will answer this question. If this form is at the base of the vertebrate stem, a detailed cytological study of many of the different kinds of cells would be of interest, and I have collected material with this end in view. The embryology of the form has never been studied and is of interest from many points of view. Starting with the fertilized egg, development was followed as far as the tornaria. Unfortunately, time did not permit a study of transformation and so many of the interesting points were missed.

For comparison, I have material of one of the ascidians, which beyond a doubt is a chordate. I have material, also, of the scorpion and hermit crab. These were collected merely to explore. The cytologist must sample many things which he does not follow up. Among the many, some things prove worth while.

Studies on the Ciliates from Tortugas Echinoids, by Philip B. A. Powers¹

During 10 weeks at Tortugas the writer studied the external morphology of the various ciliates which form the infestations found in the various species of available echinoids and collected and preserved materials for a detailed study of the internal morphology, cytoplasmic inclusions and neuro-motor apparatus. It was found that sea-urchins, when well infested, form excellent reservoirs for certain species of ciliates and are thereby splendid sources for obtaining material in abundance.

Jacobs (Year Book No. 10) was the first to describe ciliates associated with Tortugas sea-urchins. He described four species, common to *Centrichinus antillarum*, designating them as A, B, C and D. Upon reexamination, at least seven species of ciliates have been found associated with this one sea-urchin, while an examination of other echinoids has brought the total number of associated species to eleven. In the following brief descriptions, each species mentioned will be designated by a letter, pending its final taxonomic status.

GENERAL TAXONOMY OF CILIATES INFESTING ECHINOIDS

GENUS URONEMA

Form A of Jacobs is probably a member of the genus *Uronema* and has a marked affinity with *U. sociale* found in *Strongylocentrotus dröbachiensis* from the Bay of Fundy. Its approximate size is 28 by 12 μ . In shape it is

¹ At the close of the season several large sea-urchins of an unknown species were dredged from about 36 fathoms a few miles south of Tortugas. Dr. A. H. Clark of the Smithsonian Institution has identified them as members of a new species of the genus *Actinopyga*, a genus heretofore known only from the Indo-Pacific region and the west coast of Mexico and Central America. He is describing this species under the name of *Actinopyga magnifica*. An examination of the intestinal contents showed it to be infested with *Cryptochilidium bermudense* and *Anophrys* sp?; an association of ciliates common to sea-urchins taken from deep water.

greatly flattened and ovoid. Most characteristic of this form is the manner in which the pellicle is covered with rod-like bodies resembling bacteria. These small bodies will leave the surface of the pellicle immediately upon the death of the ciliate.

GENUS METOPUS

This genus has a large number either of species or of races of a single species, represented in the intestinal fauna of the various echinoids. There are four, possibly five, species of *Metopus* found among these ciliates, besides many varieties. As Kahl has pointed out, this genus is truly polymorphic and the variations among the individuals of a given species are very great.

Form B of Jacobs has been identified as *Metopus circumlabens* Biggar. This species measures about 100 (76 to 128) μ by 75 (44 to 80) μ . It is the most common form infesting *C. antillarum*.

Form J is a very large species of *Metopus* measuring 200 (170 to 300) μ long by 120 (116 to 200) μ wide. This has been found only in *C. antillarum*.

Form K is a smaller species of *Metopus* measuring about 80 (50 to 100) μ in length. This is most abundant in *Tripneustes esculentus*.

Form G is the smallest species encountered, it measures 60 (40 to 75) μ in length, and is found in *Clypeaster rosaceus*.

The final decision regarding the position of these new species, or varieties, must await further study.

GENUS ANOPHRYS

Form C of Jacobs has been identified as *Anophrys elongata* Biggar. This species is usually abundant and contains, just beneath the ectosarc, numerous refractive bodies which when treated with fumes of iodine become colored a deep indigo. The generic status of this species seems open to question as it appears to possess, in addition to the elongate row of cilia anterior to the cytostome, two small oral membranes which are usually hidden in the cytostome.

Form H is a flattened, elongate ciliate measuring 100 (95 to 140) by 28 (25 to 45) μ . The cytostome is located in the anterior region and possesses a broad undulating membrane along its right peristomal border.

Form E is closely related to *Anophrys vermiformis*; it is, however, much more slender and shorter, measuring 65 by 10 μ . The cytostome is located at the base of a broad furrow which occupies the anterior third of the body and has on its right border a wide undulating membrane, much as in *Anophrys echini*. Form E is found most abundantly in *Tripneustes esculentus*.

Form I is closely associated with E and resembles it, with the exceptions that it is smaller, measuring 28 by 11 μ , and appears to have a greater number of striations.

GENUS CRYPTOCHILIDIUM

Form D of Jacobs has been identified as *Cryptochilidium bermudense* Biggar. While this species may be found in any echinoid host, it seems to prefer *Lytechinus variegatus* or *Tripneustes esculentus*, for in these two hosts it is most often found in active stages of division. Of interest in this

ciliate is the presence of a pair of undulating membranes in the cytostome, which demonstrates its close relationship with *C. echini* of the Mediterranean.

SPECIES OF UNDETERMINED STATUS

Form F is a small flattened ciliate measuring 50 by 20 μ . The cytostome is in the right anterior portion of the dorsal surface, with a group of overhanging cilia which gives it the appearance of belonging to the genus *Entodiscus*. This ciliate has been found only in *Clypeaster* and *Encope*.

NATURE OF THE INFESTATION

In the following table are listed the various echinoids examined, the ciliates with which they may be infested, as well as the approximate percentage of individuals found harboring a particular ciliate.

The table summarizes observations on living material and will be subject to some alterations as work continues on material fixed in bulk.

Ciliates infesting echinoids

Echinoid hosts	A	B	C	D	E	F	G	H	I	J	K
	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>
<i>C. antillarum</i>	10++	100++	80++	50++	25+	—	—	10++	5+	10++	—
<i>E. lucunter</i>	10++	50++	80++	50++	25+	—	—	10+	—	—	50++
<i>L. variegatus</i>	—	5+	100++	100++	25+	—	—	—	—	—	25++
<i>T. esculentus</i>	—	20++	20++	10++	100++	—	—	—	20++	—	—
<i>C. rosaceus</i>	—	—	5+	5+	—	100++	100++	—	—	—	—
<i>Encope</i> sp.?.....	—	80++	—	—	—	100++	—	—	—	—	—
<i>E. tribuloides</i>	—	—	—	—	—	—	—	—	—	—	—

+ =rarely found. ++ =abundant, when present. — =not found.

Besides a number of forms of *Metopus* which seem to be found only in specific hosts (Form J and G) and Form F (which has been found only in *Clypeaster* and *Encope*), the majority of the ciliates encountered seem able to infest, to some degree, any of the littoral echinoids. Sea-urchins dredged from 10 to 40 fathoms are usually infested with only *C. bermudense* and *A. elongata*, while animals taken from the reefs just below shoreline have a much richer intestinal fauna. This is the available evidence upon host specificity.

In an effort to trace this infestation further, a number of holothurians, polychæte annelids and mollusks were examined. The holothurians were all negative, one of the annelids possessed a small Balantidium-like ciliate, and the mollusks often contained a few intestinal flagellates; but no trace of the "echinoid" infestation could be found in these animals.

Besides ciliates, a small red turbellarian and an occasional nematode is found in *C. antillarum*, and once in *T. esculentus* a rich infestation of flagellates was encountered.

It was found that most of these ciliates infesting echinoids live for 3 or 4 days in cool sea-water; however, efforts at their culture were not successful. A few ciliates have been observed passing out of the anus of various echinoids with the fecal pellets, which suggests a mode of transmission from host to host.

Salt Absorption and Respiration of Valonia, by F. C. Steward

The investigation consisted of a survey of the salt-absorption mechanism in *Valonia*. With due regard to the extensive bibliography upon this organism, the experiments were designed to evaluate current theories and especially to ascertain whether the general conclusions which the writer has derived from experiments with plant-storage tissues could apply even to the case of *Valonia*. The work on storage tissues has emphasized that rapid accumulation of salts occurs during periods of intense vital and metabolic activity during which the behavior of the tissue is largely determined by the variables which limit the aerobic respiration rate. The rôle of respiration seems to be rather that of a source of energy than to provide hydrion and bicarbonate-ion which, it has been suggested, may be exchanged for other cations in the case of *Valonia*, as well as storage tissue.

Previous investigators of *Valonia* have not attempted a complete control of all those variables, which in the case of storage tissues prove to be the most important. A direct comparison between *Valonia* and storage tissue has therefore been made by technique identical in all important respects with that used during recent years by the writer. The experimental vessels equipped with devices for controlled aeration and stirring were brought from Leeds,¹ along with calibrated flow meters. A source of compressed air at the laboratory together with appropriate controls permitted a rapid stream of filtered, washed air to be operated at any desired rate and for long periods of time. A specially devised metal stand supported the experimental vessels and their carbon dioxide towers, a horizontal, central, power-driven shaft and two bath stirrers to insure a uniform temperature. The metal stand was immersed in a thermostat improvised from the packing case used in transit, and temperatures were maintained within narrow limits by a flow of sea-water. Oxygen mixtures of known partial pressure were made as required in cylinders using a device kindly loaned by Professor Hoagland of the University of California. By controlling the partial pressure of carbon dioxide in the flowing stream, the reaction of the external solution could be modified over a wide range and maintained at a desired value without unduly complicating the system. Wherever possible, experiments were carried out in the dark, though experiments with cells exposed to the diffuse light of the laboratory have been made. Analyses were as far as possible carried out immediately at Tortugas. When this proved impossible, evaporated as well as liquid sap samples were preserved in sealed vials made as required from hard-glass test-tubes.

For direct comparison with the work on storage tissues, experiments were tried in which potassium bromide was added to sea-water in concentrations of the order of those used in the storage-tissue work and other variables fixed at values which would have enabled the latter tissues to accumulate rapidly both bromide and potassium. In no case did either *V. ventricosa* or *macrophyssa* show any tendency to accumulate bromide although, accompanying the slight gain of potassium, the halide content of the sap increased, but this was solely due to chloride which penetrated in preference to bromide. The absence of any conspicuous bromide accumulation is no doubt asso-

¹ The writer is indebted to Professor Priestley for permission to borrow these facilities.

ciated with the fact that during the experimental periods the cells showed no tendency to grow, produced carbon dioxide at an unexpectedly low rate and showed none of those symptoms of intense vital activity with which rapid accumulation of bromide is inseparably associated in storage tissues. All attempts to induce rapid bromide accumulation in mature *Valonia* cells failed. Attention was therefore confined to the behavior in sea-water or sea-water modified with respect to the ions K, Na and Cl.

It was first necessary to investigate a claim due to Brooks that *Valonia macrophysa* in small volumes of modified sea-water continues to gain in potassium (relative to the controls in sea-water) whether the cells were placed in potassium-rich or deficient solutions. Brooks' mixtures did not in fact meet all the desired conditions, and the comparison was made solely between the cells exposed to the modified sea-waters and the controls in normal sea-water for the same period, without any reference to the initial composition of the cell sap. Adopting technique comparable to that of Brooks, cells were exposed to a wide range of $[K] : [Na]$. This was done by two methods. The first maintained the normal chloride concentration of sea-water and in the second the desired concentrations were obtained by addition of the alkali chlorides to sea-water. The final sap composition from cells in the modified sea-waters was compared with the controls from similar volumes of normal sea-water and also with the initial sap obtained from comparable batches of cells. The effect which Brooks claimed to demonstrate only appears in the mixtures in which the chloride concentration as well as the $[K] : [Na]$ deviated from the value in normal sea-water. If the chloride concentration remains constant, *Valonia* cells may be exposed to a wide range of $[K] : [Na]$ without appreciable effect upon the composition of the sap. A similar series of experiments with *Valonia ventricosa* led to an identical result. It appears probable that the theory which Brooks based upon his observations will require reconsideration.

The most significant fact which emerges from these experiments, and one which could not be ascertained from Brooks' data, is that by exposing *Valonia* cells to relatively small volumes of solution in the diffuse light of the laboratory under conditions reducing evaporation to a minimum, *all* the cultures, including those in sea-water, gain very considerably in potassium and far in excess of the corresponding gain of chloride. In short, adopting the technique of Brooks, it is clear that the potassium content of the cells is not determined either by the $[K] : [Na]$ or the $[K]$ itself within the wide limits studied, but by some other unspecified variable. Many variables are affected when *Valonia macrophysa* cells are transferred from the moat of Fort Jefferson and eventually allowed to remain in contact with solutions which approach equilibrium with air in the diffuse light of the laboratory. In the moat, the cells are exposed to considerable diurnal changes of oxygen and carbon dioxide concentration and subject to illumination which differs drastically both in the duration and quality of the incident light from that of the laboratory. In order to gain further knowledge upon these factors, a brief study was made of the normal diurnal fluctuations in sap-content, utilizing cells from the moat and also from a more isolated pool in which analysis showed that the conditions were even more extreme. These samples await analysis.

Preliminary experiments suggested that the potassium absorption of *Valonia* is affected by aeration. For the critical experiments upon the behavior under conditions of controlled aeration, a population of 1200 *Valonia ventricosa* cells from Bird Key Reef was utilized. They were rigorously graded by size into six classes and in this series of experiments particular attention was paid to their specific surface—the more so because after but a limited sojourn in a running-water aquarium, the cells showed a perfectly definite relationship between cell size and potassium content. Published figures for this organism would approximate to a composite sample drawn from cells of various sizes. There is no direct reason to suppose that this effect originated in the aquarium, although it disappeared after a period in potassium-enriched and aerated solutions. Further collections covering a similar size range were made and the sap immediately extracted and preserved for future analysis.

The carbon dioxide production of *Valonia* is so low that when appropriate blanks to eliminate the possible errors have been utilized, no significant effect of cell size could be detected. A single determination of oxygen consumption of *Valonia* using the Winkler method yielded a definite but low value. Time did not permit this to be done for a range of cell sizes.

Two series of experiments, covering the oxygen partial pressure range from 0.5 to 100 per cent and using at each oxygen tension a range of cell sizes in both normal and modified sea-water, were carried out. Since aeration with carbon dioxide-free air modifies the reaction of sea-water, the effect of the external pH upon salt absorption was studied by using four different air/CO₂ mixtures in which the partial pressure of carbon dioxide varied from zero up to a value adequate to maintain in sea-water a pH of 5.6. This treatment was utilized under conditions of darkness and diffuse daylight, using both normal sea-water and sea-water enriched with potassium chloride.

It is anticipated that when complete, the data will shed considerable light on the physiology of *Valonia*. It is already evident, however, that results obtained from these cells, which are transferred from a narrowly defined habitat to laboratory or experimental conditions where their sap composition may be affected by numerous variables, must be interpreted with caution—especially where due control has not been exercised. Even greater caution should attend attempts at generalization from the special case of *Valonia* to actively growing and metabolizing cells in which the vital processes may play a more intimate part. Experiments on *Valonia* seem to be mainly concerned with cells which have either ceased active growth or at best are only sluggishly extending. Further detailed knowledge concerning the respiratory mechanism of *Valonia* and particularly of its manner of growth, especially during its period of rapid synthesis and extension if any, seems to be required in order that the salt absorption mechanism may be more fully interpreted.

Transplant and Succession Studies on Marine Algæ, especially Caulerpa and Halimeda, by Geoffrey Tandy

The transplants of *Caulerpa* and *Halimeda* were made with the object of finding the limits of the species. The first experiments were made by moving

specimens from the open reefs to a pool in the moat of Fort Jefferson. The pool is close against the wall of the fort, is cut off from the sea by encroaching coral shingle and gets no direct sun until between 11 a.m. and noon. At the beginning of June it had a dense, pure stand of *Caulerpa racemosa* var. *occidentalis* (Ag) Boerg. (Taylor, *Marine Algæ of Florida*, 102).

Into this pool various forms of *Caulerpa* were moved and all showed some change. Two "varieties" of *C. racemosa* produced the var. *occidentalis* either by proliferation from the old axes or from new stolons. *C. sertularioides* and *C. cupressoides* produced the "varieties" native to the moat, recorded as such by Taylor. Striking success was obtained in causing *C. peltata* to produce shoots, though small, of the form of *C. racemosa*, thus demonstrating the affinity suspected by Mme. Weber-van Bosse in her 1898 monograph, when she placed it as a subspecies under *C. racemosa*, a position much questioned by subsequent workers. Thus it is possible to show that at least seven "varieties" and one "species" are nothing but ecological forms of three species.

Halimeda opuntia is credited (for the Dry Tortugas) with three varieties. Of these the var. *typica* proliferates the var. *triloba*. *Halimeda tridens* will proliferate *H. monilis*.

Two matters of interest arise from the succession studies. The first is that the numerical relations between the oriented faces of blocks were not confirmed (See Year Book No. 30). The second is that an organism of widely different affinities took the place of *Hormothamnion enteromorphoides*. It is, I believe, undescribed, but it has the same equipment as *Hormothamnion* in that it makes a very quick regression to a plankton phase.

Studies on the Life Histories of Algæ, by Shigeo Yamanouchi

Since the general survey of 1929, my attention has been given particularly to the blue green (1930), the brown (1931), and the red algæ of Tortugas (1932). During the summer of 1933 the study was continued with emphasis upon life histories. Results obtained are in part as follows.

WITH RESPECT TO FIXATION

Cytologists know only too well that fixation presents most difficult problems. Some, and some physiologists, scarcely expect to obtain dependable results from fixed material. Yet the necessity of using high magnifications in determining the real physical structure of the cell requires every possible improvement in the technique of fixation, sectioning and staining, for theories based upon poorly prepared material unfortunately introduce erroneous ideas of nucleus and protoplasm.

The most delicate filamentous forms, such as *Ceramium* and some others of the red and the brown algæ, are most satisfactorily fixed in Flemming's weak fixing fluid diluted 20 to 25 times with sea-water. The length of time in the fluid differs according to the material, but the shortest needs to be only half a second. Washing should be done in 50 per cent alcohol without sea-water.

STRUCTURE OF CHROMOSOMES

It seems clear that at least the larger chromosomes, as seen in sections, are aggregates of smaller granules, and in certain cases it seems justifiable to maintain that the number of granules is constant. This conclusion may seem rash, since protein so often coagulates in the form of minute granules and the problems rising here lead into a region beyond the present reach of our technique. Nevertheless the cytological evidences point unmistakably to the conclusion that chromosomes arise from spireme threads which are serial aggregates which have a perfectly definite organization differing specifically from chromosome to chromosome and from species to species.

The chromosomes and chromomeres of the blue-green algæ present most important material for study of the phylogenetic origin of these structures.

Detailed presentation of results will be made later, but the number of chromosomes in some of the blue-green and green algæ may here be set down:

BLUE-GREEN ALGÆ

<i>Chroococcus membranicus</i>	16
<i>Chroococcus turgidus</i>	18
<i>Chroococcus</i> sp.	8
<i>Hydrocoleum lyngbyaceum</i>	14
<i>Lyngbya confervoides</i>	12
<i>Lyngbya majuscula</i>	18
<i>Phormidium hendersonii</i>	12
<i>Phormidium</i> sp.	16
<i>Phormidium</i> sp.	14

GREEN ALGÆ

<i>Enteromorpha flexuosa</i>	12
<i>Rhizoclonium hookeri</i>	18

PLASTIDS

Recent workers (Levitsky, Guillermond, Meves, Dangeard and others) have adduced weighty evidence to show that plastids are of the same nature as chondriosomes and are actually derived from them in the course of development. Many forms such as *Codium*, *Halimeda* and *Penicillus*, among green algæ, *Dictyota* and *Ectocarpus* among brown algæ, *Liagora*, *Scinaia*, *Ceramium*, *Herposiphonia* and *Erythrotrichia* among red algæ, present a situation confirming their view.

ASTRONOMY

Albrecht, Sebastian, Dudley Observatory, Albany, New York. *Studies of radial velocities.* (For previous report see Year Book No. 31.)

In continuation of the problem of wave-lengths in the spectrum of a typical star of each spectral class, the work on α Canis Minoris, which has been delayed to take advantage of a new set of spectrograms on the process emulsion, has now been brought to completion and will soon be published. Additional spectrograms, secured in November 1932, have been measured and reduced. On the new plates, the widths of the lines were also measured in addition to their positions. The new data greatly increase the certainty with which the presence or absence of lines of known origin can be assigned to measures of stellar lines.

At the Chicago meeting (June 1933) of the American Astronomical Society, a paper was presented on "Procyon, a spectroscopic binary of very short period." Procyon was known to be a close visual binary, magnitudes 0.5 and 13.5, with a period of 40.2 years. Means of radial velocities, grouped according to epoch of observation, have been published for 114 spectrograms taken at the Lick Observatory and for 119 spectrograms taken at the Cape Observatory. The Lick means vary from -0.5 to -5.2 km./sec. Due to its orbital motion about the center of gravity of the pair, on the basis of a recent orbit by H. Spencer Jones, the bright star should vary in radial velocity with respect to the sun from -2.3 to -4.9 km./sec. Thus, the observed range of the Lick means is nearly twice as great as the computed range. Moreover, in 1909 Dr. W. W. Campbell noted the fact that the Lick measures, covering an interval of 13 years, did not agree well with a period of about 40 years.

The writer has obtained the following radial velocities from measures of numerous lines on spectrograms taken at the Yerkes Observatory with the dispersion of three prisms:

Plate	G. M. T.	Observed velocity reduced to Sun	Ephemeris from 40-yr. period
B467	1902, Nov. 27.924	-7.2 km./sec.	-4.5 km./sec.
B881	1917, Mar. 19.656	$+1.8$	-2.8
R1963	1932, Nov. 5.365	-4.9	} -4.8
R1972	Nov. 14.340	-3.2	
R1973	Nov. 14.415	-10.5	
R1986	Nov. 24.384	-5.1	
R1987	Nov. 24.431	-5.6	

The results given in the table confirm and explain the discordance noted by Campbell. These measures show a total range of 12.3 km./sec. The light of the faint visual companion makes no contribution to the spectrogram. Considering the great number of plates measured at the Lick and

Cape Observatories and the observed variation of 7.3 km./sec. in an interval of only one hour and eight minutes (on November 14), it seems entirely safe to conclude that Procyon is a triple star, the bright component of the visual pair being a spectroscopic binary, with a total range of variation in velocity of about 12 km./sec., in a period of the order of one-fourth of a day. Procyon thus takes its place among the six other spectroscopic binaries of known period less than a day.

BIOLOGY

Cannon, W. A., Stanford University, California. *Further studies on the oxygen consumption of roots when in distilled water.*¹ (For previous reports see Year Books Nos. 2, 5, 8, 9, 11-25, 30 and 31.)

The purpose of this report is to give evidence, in addition to that already presented in the references cited, that the oxygen used by plants, including the roots, may be in part and regularly derived from the chlorophyll-bearing tissues when the shoot is exposed to proper light.

OXYGEN ABSORPTION BY ROOTS OF SALIX

When the shoot of *Helianthus annuus* L. and *Salix laevigata* Bebb is exposed to sufficient daylight, especially during the middle of the day, the amount of oxygen removed from the solution, with respect to oxygen absorption while the shoot is in dense shade, is relatively small in amount;² also experiments in which the shoot of *Salix* has been placed in direct sunlight for half an hour at 8^h30^m and 10^h15^m and 2^h14^m p.m. and 2^h30^m p.m. give essentially the same results. Moreover, in some instances where the exposure to direct sunlight followed a period of darkness, there was found an increase in the oxygen content of the solution.

Where the shoot is kept continuously in dense shade during an experiment of 7 hours or less, the amount of oxygen absorbed falls in rate, appearing to parallel the decrease in the oxygen content of the solution. But, on the other hand, when the shoot is exposed continuously to sunlight, the rate of oxygen absorption remains relatively uniform. At the outset and shortly after having been exposed to sunlight, the rate falls markedly, but later it rises and continues somewhat less than would be expected if the shoot were in darkness. This feature points to a possibly two-fold origin of the oxygen utilized by the plant, including the root, namely from the immediate environment of the root and through the photosynthetic processes of the shoot.

OXYGEN ABSORPTION, TRANSPIRATION AND EVAPORATION

When a shoot is exposed to direct sunlight, the rate of transpiration increases at once, but, on the other hand, the rate of oxygen absorption by the root is not immediately affected. A lapse of about 30 minutes occurs before the expected decrease in oxygen absorption can be detected.

In some instances increase in the rate of evaporation is associated with an increased rate of oxygen absorption, but, when a high evaporation rate obtains through the entire light period, the general course of oxygen absorption by the root appears to be the same as when the evaporation is less.

ON ABSORPTION OF WATER BY UNINJURED SHOOTS IN PLACE³

At present it is not known how oxygen, which may take its origin in photosynthesis, may move from the leaves toward or to the root, although that

¹ The research was carried out in part with the aid of a grant from the National Research Council and also with the assistance of Dr. Delzie Demaree.

² W. A. Cannon, *Absorption of oxygen by roots when the shoot is in darkness or in light*, Plant Physiol., vol. 4, 673, 1932.

³ By Dr. Demaree.

such must occur is a corollary of the main findings presented in this report. One means, however, by which such movement may take place is suggested by the following studies. Large specimens of cardoon (*Cynara cardunculus* L.), growing on the campus of Stanford University, were used in the experiments. The method of procedure was to submerge the leaf tips, for various but limited periods, to a depth of about 10 cm. in water in which dyes had been dissolved. As a result, it was found that water was taken up and passed down the leaf to and into the upper portion of the root. In certain instances, as determined by the staining, the water went so far as 2 meters in 4 hours. As much as 750 c.c. was taken into the leaf in this manner in 8 hours. Records of the evaporating power of the air by Livingston atmometers, the temperature of the air, the moisture content of the soil as well as the moisture content of the leaves, were kept and showed that in general the greatest water absorption was concurrent with greatest water deficit.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-31.)

Good progress has been made in the past year in the studies of inheritance in rabbits outlined in previous reports.

There are three different races of short-haired (rex) rabbits. Crosses between any two of these result in the production of normal-haired young. This shows that the physiological process which results in the production of short hair is in each race a different one. A recessive gene mutation is responsible for each, but each race results from mutation in a *different* gene.

An attempt has been made to determine by linkage studies whether these three genes are borne in the same chromosome or in different chromosomes. The answer to this question is that two of the three genes are borne in the *same* chromosome, whereas the third is borne in a different chromosome. The evidence is as follows:

When rex_1 is crossed with rex_2 , normal offspring result in F_1 , but in F_2 approximately equal numbers of short-haired and normal individuals are obtained. We have recorded exactly 167 of each sort. If the two rex genes were located in *different* chromosomes, we should expect in F_2 a 9:7 ratio of normal to short haired. If they are located in the *same* chromosome pair and little or no crossing over occurs, we expect equal numbers of normal and short haired to be produced in F_2 , which is the observed result. That a certain amount of crossing over *does* occur between the genes r_1 and r_2 , has been experimentally demonstrated, and the amount is indicated as being approximately 10 per cent. We conclude that the genes r_1 and r_2 lie in the same chromosome at loci about 10 units apart. All but the last step has been taken in the synthesis of a race homozygous for both r_1 and r_2 . What its somatic character will be, if it is viable, and whether it will indeed prove to be viable are questions which we hope to answer shortly.

The third rex race results from mutation in a gene which does *not* lie in the same chromosome as genes r_1 and r_2 . For when rex_3 is crossed with either rex_1 or rex_2 , an F_2 generation is obtained which contains more normal than short-haired individuals, the ratio approximated being 9:7. From the

$r_1 \times r_3$ cross we have an F_2 population of 127 normals:92 short haired, expectation on a 9:7 basis being 123:96. From the $r_2 \times r_3$ cross we have a population of 86 normals:49 short haired, expectation being 76:59. Deviation in both cases from the 9:7 ratio is *away from* equality not toward it, but is no greater than random sampling might produce.

The chromosomes in which these rex genes lie have not as yet been identified as being linked with any other known gene of the rabbit, but our studies of this question are still incomplete.

The two blood-group genes described in my last report have been found to be allelomorphs, as are the blood-group genes of man. No linkage has as yet been found between them and any other known gene of the rabbit, though the canvass of the possibilities is nearly complete. Consequently they may constitute the marker of a chromosome pair as yet untagged.

Linkage studies in yellow fat inheritance in rabbits show that the gene for fat color lies between the genes for albinism and brown-coat color. Several years ago I showed that a loose linkage (about 35 per cent crossing over) occurs between albinism and brown. Later Pease discovered the character yellow fat and showed it to be linked with albinism. It should accordingly be linked also with brown, on the chromosome theory. This is actually the case. In a backcross population of 434, I find the crossover percentage between the color gene (C) and the yellow fat gene (Y) to be 14.7; while the crossover percentage between Y and the black-brown gene (B) is 26.3. The sum of these two (the map distance between C and B) is 41.2, but the observed crossover percentage between B and C is in this case 38.9. The difference between these two amounts, 41.2 and 38.9, is accounted for by the occurrence of 10 *double crossovers*, *i.e.* crossovers occurring simultaneously between C and Y and between Y and B. If a break occurred in one of the two segments, *independently* of its occurrence in the other, we should expect to have about 17 double crossovers instead of 10. Hence there is "interference" in crossing over in mammalian chromosomes, as well as in those of *Drosophila*. This is a matter of interest because the present case is the first one to be studied in which a comparison is possible. Linked genes in mammals have, in all previously studied cases, been too few or too closely crowded to demonstrate the occurrence or non-occurrence of double crossing over.

Dr. C. E. Keeler, besides giving instruction in genetics at the Medical School, has cooperated effectively in the blood-group studies in rabbits and has carried on intensive studies of mouse genetics. Dr. P. B. Sawin is continuing studies in rabbit genetics partly at the Bussey Institution, partly at Brown University. Mr. F. H. Clark has completed a study of a new spotting gene discovered in a stock of laboratory mice, which is associated with a non-lethal form of anemia present at birth but from which, under favorable conditions, the animal recovers. He has also discovered, and is studying, in mice an ordinarily lethal variation, hydrocephalus (water on the brain), similar to the condition found in man. It is inherited as a recessive character. Mr. S. C. Reed is making a study of a mouse variation commonly lethal, harelip and of several other mutant characters which he has under observation.

Dice, Lee R., University of Michigan. *Ecological studies of Arizona mammals*. (For previous report see Year Book No. 31.)

Philip Blossom made two trips to southwestern Arizona and northwestern Sonora during the past year. On the first expedition he was in the field from September 25 to October 25, 1932; and on the second expedition from April 20 to May 18, 1933. Principal localities studied were Telegraph Pass in the Gila Mountains, Raven Butte, Tinejas Atlas, Tule Tank, Cabeza Prieta Mountains and the nearby Crow Butte, Agua Dulce Mountains, Pinacate Mountains in Sonora, and the Pinacate Lava Plain in southern Arizona. Several of the mice and woodrats taken prove to be new species and subspecies and are being described in preliminary papers.

The various mountain ranges of the desert rise like islands from the sea of desert sand, and the animals living in rocky habitats therefore have discontinuous ranges. The colonies living on each mountain range are isolated, more or less completely, from the other colonies of the same species occurring on other mountains. It is found that the pelage color of the rodents on the different mountain ranges varies considerably, and in general the color of the rock-living rodents is closely correlated with the color of the rocks on which they live. The area of rocky habitat, completeness of isolation and degree of dominance of one color tone in the rocks are important factors affecting the amount of correlation between rodent color and rock color. Species most affected are the rock pocket-mouse (*Perognathus intermedius*), cactus mouse (*Peromyscus eremicus*) and white-throated woodrat (*Neotoma albigula*). Climatic conditions obviously can not play an important part in these color modifications, for the climate of the desert is relatively uniform over the area studied.

The deer-mice (*Peromyscus maniculatus*) of the upper forested parts of the Santa Catalina mountains are much darker in pelage color than are the mice of the same species living at the upper edge of the desert on the lower northern slope of the range. These differences in pelage color are perhaps correlated also with the soil colors, for the humus-filled soils of the mountain forests are much darker in color, especially when damp, than are the soils of the very dry lower mountain slopes.

The study of the mammalian communities of the Santa Catalina Mountains, begun in June 1932 by Dr. Dice, was continued until late July, when the field of study was shifted for two weeks to Miller Canyon in the Huachuca Mountains.

While the Santa Catalina Mountains are practically surrounded by deserts, the Huachuca Mountains rise from a much higher base-level, where the vegetation is dominated by arid grasses, mixed with a few thorny shrubs. The mammalian communities of this arid grassland are quite different from those of the desert. The oak belt (encinal) is well developed on the lower slopes of both ranges. Although the highest peaks of the two ranges reach nearly the same altitude, the forests of the upper Huachuca Mountains are much less dense than those of the Santa Catalinas and some of the dominant tree species are different. The difference in vegetation on the two ranges indicates some differences in the mammalian environments.

In the Huachuca Mountains time was not available for detailed ecological studies, but apparently the only important difference in mammalian fauna between the two ranges is that the chipmunk (*Eutamias dorsalis*), which is abundant in the forests of the Santa Catalina Mountains, is absent entirely from the Huachuca Mountains and no species of chipmunk occurs in that range. On the grassland east of the Huachuca Mountains the cotton rat (*Sigmodon*) and the white-footed mouse (*Peromyscus leucopus*) were found to be common, while these species are rare near Tucson.

An ecological survey of the Chiricahua Mountains of southeastern Arizona was begun in late June 1932 by Victor H. Cahalane, of Cranbrook Institute of Science, Bloomfield Hills, Michigan. Field work was carried on until mid-September, and was continued in 1933, beginning in June. During the 1932 season trapping was carried on in the high mountains between Fly Peak and Chiricahua Peak at an elevation of 9500 feet in an area of Engelmann spruce and aspen. In the yellow pines at Rustler Park (elevation 8300 feet) a number of trapping stations was established. The oak life belt was investigated in the South Fork of Cave Creek and in the vicinity of Paradise, at about 5300 feet. Specimens were also secured from the desert east of Postal at about 4000 feet. The work of the 1933 season should give a fairly complete picture of the mammals communities of the various life belts from the upper desert to the cool spruce-covered mountain tops.

The mammals living in the important vegetational types of each life belt have been determined by extensive trapping. Although the ranges of some species extend into several forest types and life belts, a gradual succession of forms is apparent in going from the base to the summit of the range.

A number of dark-colored races of rodents have been described by previous investigators from the lava beds of the San Francisco Mountains region in northern Arizona. An intensive study was made of the mammals of these lava beds and of the surrounding areas by G. W. Bradt, of Michigan State College. Mr. Bradt was assisted in this investigation by A. M. Stebler, A. J. Nicholson, R. K. Knox and H. G. Walt. The period spent in the region extended from July 1 to August 2, 1932.

On the younger lavas of the region, mammals of all kinds are few and seem in general to be not at all different in color from those occurring on rocks of paler colors in the same vicinity. The older lavas of the region are much weathered and overgrown by vegetation and the dark color of the rock is therefore much obscured. The dark races of mammals which are associated with these old lavas are by no means so dark in pelage color as are the races of mammals associated with some of the black lavas of New Mexico and Arizona.

Longley, W. H., Goucher College, Baltimore, Maryland. *Preparation of a monograph on The Tortugas fishes.* (For previous report see Year Book No. 31.)

The interval from February 10 to May 20, inclusive, was spent in study of types and other specimens of West Indian fishes in European museums. Facilities freely placed at my disposal in the British Museum, the Museum

d'Histoire Naturelle in Paris, the museums of natural history in Vienna, Berlin, Amsterdam and Leiden, and the museum of the Biological Institute of the University of Lund, have notably advanced my project. As a result of this experience abroad and of renewed examination of material in the Museum of Comparative Zoology of Harvard University, the American Museum of Natural History, the museum of the Academy of Natural Sciences in Philadelphia, and the U. S. National Museum, it is possible to reduce further the valid names in the West Indian list. Several of the following have been earlier in synonymy, but for most reduction is here proposed for the first time:

- Cetengraulis gilberti* (Evermann & Marsh) = *C. garmani* (Evermann & Marsh) = *C. edentulus* (Cuvier).
Syngnathus torrei Nichols = *Doryichthys lineatus* Valenciennes.
Hippocampus kincaidi Townsend & Barbour = *H. brunneus* Bean = *H. styliifer* Jordan & Gilbert = *H. punctulatus* Guichenot.
Epinephelus angustifrons (Steindachner) = *E. morio* (Cuvier & Valenciennes).
Chaetodon gracilis Günther = *C. sedentarius* Poey.
Pomacanthus rathbuni Miranda Ribeiro = *P. arcuatus* (Linnæus).
Pomacentrus rubridorsalis Beebe & Hollister = *P. adustus* Troschel, *juv.*
Halichoeres kirschii (Jordan & Evermann) = *H. poeyi* (Steindachner).
Cryptotomus beryllinus Jordan & Swain = *C. auropunctatus* (Cuvier & Valenciennes).
Sparisoma rhomaleum Meek & Hildebrand = *S. spinidens* Guichenot.
Sparisoma erythrinoides (Guichenot) = *S. distinctum* Poey.
Sparisoma maschalespilos (Bleeker) types = *S. chrysopterum* (Bloch & Schneider) and *S. squalidum* (Poey).
Scarus quadrispinosus Cuvier & Valenciennes = *S. tæniopterus* Desmarest.
Scarus aracanga Günther = *S. flavomarginatus* Cuvier & Valenciennes = *S. punctulatus* Cuvier & Valenciennes.
Pseudoscarus pleianus (Poey) = *P. guacamaia* (Cuvier).
Auchenopterus affinis Longley (♀) Carnegie Inst. Wash. Year Book, No. 31, p. 300 (?*A. affinis* (Steindachner) = *A. nigripinnis* (Steindachner)).
Paraclinus chaperi (Mocquard) ♂ = *Auchenopterus fasciatus* (Steindachner).
Labrisomus guppyi (Norman) = *L. heilneri* Nicholas = *L. bucciferus* Poey = ?*L. gobio* (Cuvier & Valenciennes).
Malacotenus biguttatus (Cope) = *M. gillii* (Steindachner).
Entomacrodus decoratus Poey = *E. nigricans* Gill = *Salarichthys textilis* (Quoy & Gaimard).
Ophioblennius ferox Beebe & Tee-Van = *O. webbii* (Valenciennes).
Acanthemblemaria variegata Beebe & Tee-Van (♀) = *A. arborescens* Beebe & Tee-Van (♂) = *A. spinosa* Metzelaar.
Monacanthus spilonotus Cope = *M. hispidus* (Linnæus).
Monacanthus amphioxys Cope = *Cantherines pullus* (Ranzani), *juv.*
Davidia punctata Miranda Ribeiro = *Alutera punctata* Jordan & Evermann = ?*A. punctata* Agassiz = *A. schoepfi* (Walbaum), *juv.*

Measured against Jordan, Evermann and Clark's *Check List* (1930), the rectified list of last year¹ and this year together relegate to synonymy about 113 species and 8 genera. With continued study the number of the former will increase materially—by no indiscriminate lumping, but as the result of close study of the taxonomic record and of museum specimens, supplemented by study of living fishes. When the inquiry is complete it will appear that roughly 20 per cent of the names of West Indian fishes at present recognized in the *Check List* have no independent standing. The fact comes to light incidentally in a review of which the prime purpose is to determine the

¹ The suggestions regarding synonymy under *Harengula* are premature; *Syngnathus robertsi* (Jordan & Rutter) is the same as *S. elucens* of some authors, but probably not the same as *S. elucens* Poey; *Cryptotomus crassiceps* Bean is the male and not the female of *C. roseus* Cope, as inadvertently stated.

correct specific names of the teleost fishes of Tortugas. With its implications it is interesting.

For the same reasons that superfluous names for West Indian fishes so abound, they must tend to occur in excess in all groups. The taxonomist has always been obliged to order his material with insufficient knowledge of the living organism. Necessity compels him too to depend largely upon published descriptions rather than upon comparison with type material for the identification of his specimens. And always the fact that reputations are made at least temporarily by the erection of new genera and species with which his name may be associated tempts him to set up such new groupings when he may, *not when he must*.

The necessary effect of the existence in all large groups of many specific ratings for which there is no foundation in fact is pernicious. It paves the way for unwarranted subgeneric and generic divisions. It fosters the impression that species are groups much less sharply distinct than they actually are. It tends to obscure the truth that the bases of taxonomy are objective; that taxonomy itself is not an art but a science—a science too of unique interest whose numerical data upon statistical analysis supply the answer to some of biology's most difficult questions, since its groups truly conceived are the only authentic product of organic evolution under natural conditions.

For a very good reason it is possible to admit so much error in the record and still make the last statement. A sufficiently large body of error upon being itself analyzed permits one to determine the cause of confusion, or at least to determine what correction must be applied to offset its effect.

Limitations of space forbid elaboration of the last point in detail. The outstanding facts to be reported, however, are that the review of West Indian fishes, required before those of Tortugas may be known under their proper names, proceeds more slowly than was anticipated; the review incidentally makes available for study a long series of errors which have crept into the taxonomic record; these errors betray their causes and permit the application of corrections in the course of statistical analysis; so corrected, the results of analysis shed a new and clear light upon the evolutionary process.¹

These findings and a substantial addition to the finished manuscript represent the progress made since my last report was submitted.

Mann, Albert, Washington, District of Columbia. *Continuation of investigations and preparation for publication of results of studies on Diatomaceæ*. (For previous reports see Year Books Nos. 18–31.)

In consequence of commercial inactivity throughout the country, requests from outside parties for diatom information, named specimens and samples of diatomite have fallen off greatly during the past year. This has afforded more time for independent diatom research in our laboratory. There have been, however, some requests received and acted upon that are deserving of special mention.

Three samples of reputed diatom earth were examined for S. W. Briggs of Washington, D. C., who is experimenting with a filtering device for

¹ See *Nature*, vol. 131, 863, June 17, 1933.

clarifying lubricating oils in automobile engines. The samples were found to be finely ground quartzite and wholly destitute of diatoms.

Four samples of subterranean mud from depths of 65 to 80 feet in Lake Mendota, Wisconsin, were reported on for Dr. E. B. Fred, Department of Agricultural Biology, University of Wisconsin. The information desired was to be used in connection with Dr. Fred's bacteriological studies of this and other deep lake muds. Microscopic studies of the samples showed them to be composed chiefly of the silica remains of diatoms. All species were named in the report sent.

A sample of marine algæ, sent by Professor Manuel Valerio, Lyceum of Costa Rica at San Jose, was collected on the west coast of that country. The material yielded 54 species, a list of which was mailed to Professor Valerio.

Some microscope slides of the giant diatom, *Coscinodiscus rex* Wall., were loaned to Philip O. Gravelle, South Orange, New Jersey, a professional in commercial photomicrography. They enabled him to make some exceptionally fine photographs of this huge but very delicate species. It is a plankton form living in the middle Pacific Ocean.

Diatoms found in three samples of material taken on the oyster beds in Delaware Bay belonging to the State of New Jersey were examined and identified for Dr. Thurlow C. Nelson, Professor of Zoology at Rutgers College and head of the New Jersey State Oyster Investigations. The conservation of the State's valuable oyster beds is being handled by practical, up-to-date methods, including a study of the quality and quantity of the oyster's food, of which diatoms constitute from 40 to 60 per cent.

Diatom earth, as a constituent of cement used in making concrete highways, is becoming extensively employed. Photographs of diatoms common in such material were supplied on request to Ira B. Mollis, Highway Engineer, Omaha, Nebraska.

The diatoms found in some material collected in Yellowstone Park were identified for the collector, Mr. Arthur Nash of the University of Minnesota.

Some fossil diatom species unknown to Mr. V. L. Eardley-Wilmot, Geologist of the Canadian Bureau of Mines, Ottawa, Canada, were identified and mounted specimens of two of them were supplied.

A detailed supplementary report, with several photographs, of diatoms found in British Columbia lakes were sent to Dr. Wm. R. Taylor, Department of Botany, University of Michigan. It is to be added to an extensive report on the diatoms of that region prepared by Mr. Conger and previously delivered to Dr. Taylor and will be incorporated in Dr. Taylor's forthcoming paper on the biology of the lakes.

A letter from Mr. Richard Armstrong, Commissioner of Fisheries of Virginia, with whom previous correspondence had taken place, detailed the great need of some text-book in marine life adapted to use in the public schools of the State, especially in the "tidewater section"; Mr. Armstrong's purpose being to create interest among the scholars in "what the sea means to them." This novel innovation on the part of the State Commissioner, he states, is due to his inability to secure adequate resources for carrying on operations for preserving and improving the fish and oyster interests of the Virginia coast. A letter of commendation of this project was written

and sent with a copy of *The Economic Importance of the Diatoms*, a considerable part of which deals with this subject.

Many minor requests for diatom information were received during the year, to all of which suitable replies were furnished.

The study of dredgings made by the *Carnegie* on its last voyage has been completed, a full report written and some necessary tabulations prepared. Although there were few strictly diatom dredgings made and still fewer were from bays and harbors visited by the ship, those made in deep-sea areas for topographical purposes have yielded some very suggestive results. As living diatoms can not exist in material secured from the sea's profound depths it follows that the dead specimens which were found must have been transported from the localities where they grew and deposited at the places where the dredgings were made; this transportation being effected by ocean currents or, in the case of plankton forms, by surface drift due to prevailing winds. A surprisingly large proportion of species occurred in some of these gatherings; and in cases where such a diatom assemblage is found to be practically identical in the composition of its flora with that growing in some harbor or arm of the sea, the presumption is warranted that a case of ocean current transportation between the two places exists. This supposition is greatly strengthened if a species, that has never been found elsewhere, occurs in both places. Several correspondences of this kind were discovered, and all the facts bearing on this subject are being assembled in the final division of my report. It should be added that when sufficient confirmatory data of this kind has been secured, there will be established full proof of the value of diatoms as a means of detecting the trend and extent of ocean currents.

Work has been carried to completion on some rich marine material collected by Mr. W. A. Robinson during his three-years' voyage in a small ketch to remote places in the South Pacific Ocean and the East Indies. This collecting was done at the suggestion of Captain Ault who met Mr. Robinson at Pago Pago, Samoa.

Early this Spring, Mr. Robinson visited our laboratory and announced his intention of making a second similar voyage, his plan being to start in June. Arrangements were made with him for further diatom collecting during the new voyage. Two diatom dredges were made and were sent with 50 special collecting bottles to his ship address at Great Neck, Long Island, New York. Mr. Robinson and wife have already started on this second voyage.

Mr. Conger, having last year spent about a month at Solomons Island in Chesapeake Bay, Maryland, engaged in very satisfactory collecting, returned this summer for a somewhat longer period. The work is carried on in connection with the marine biological laboratory established there under the auspices of the University of Maryland. Our diatom work at Solomons Island is planned to be cooperative with the oyster investigations of the State of Maryland. Mr. Conger has taken advantage of his location for the summer, to give a series of lectures on methods of collecting and studying marine diatoms, together with instructions in the biological laboratory of the scope of the science as a whole, its principles of classification and the art of accurate illustration of specimens.

Morgan, T. H., C. B. Bridges and Jack Schultz, California Institute of Technology, Pasadena, California. *Constitution of the germinal material in relation to heredity.* (For previous reports see Year Books Nos. 15-31.)

New mutants continue to appear, many of them useful in filling out certain gaps in the chromosomes. A thorough revision of the chromosome maps is under way, based on an accumulation of linkage data. Some of the more special problems that have been studied in the last year are here briefly described.

Crossing-over, multiple crossing-over, and the relations between crossing-over and recombination have been studied for the entire length of the X-chromosome by use of the loci yellow, bifid, crossveinless, cut, vermilion, garnet, Bar and bobbed. The crossing-over values for two complementary experiments are given in the accompanying table and are practically identical with those previously obtained for the different set-up and independent data for "alternated Xple." A set of correction curves showing the numerical difference between crossing-over and recombination has been prepared from the new data. The values are practically identical with those for alternated Xple (see fig. 1, page 234, Carnegie Year Book No. 24) as far as those were based on direct observation, namely, for the entire region from scute (yellow) to forked (Bar). Furthermore, the predictions by extrapolation (in parentheses below) for the region to the right of Bar have been realized by the new data as follows: y-bb, 26.2 (26.0); bi-bb, 19.3 (18.5); cv-bb, 14.4 (13.4); ct-bb, 8.8 (9.0); v-bb, 2.8 (2.5); g-bb, 0.4. The complementary experiments in which bobbed-lethal was used instead of bobbed gave lowered crossing-over in the regions nearest bobbed-lethal, which was expected in accordance with the probable deficiency nature of bobbed-lethal.

Linkage system	N	y-bi	bi-cv	cv-ct	ct-v	v-g	g-B	B-bb	Total
y ² cv v B bb/bi ct ⁶ g ²	2,731	8.7	7.7	8.3	16.2	10.0	11.5	12.8	75.3
y ² cv v B/bi ct ⁶ g ² bb	2,247	8.4	8.0	9.3	13.4	10.9	11.8	13.0	74.8
Combined bb data	4,978	8.6	7.9	8.7	15.0	10.4	11.6	12.9	75.1
Alternated Xple	26,908	8.6	7.9	8.4	14.8	11.2	11.6	(12.5)	75.0
y ² cv v Bbb ¹ /bi ct ⁶ g ²	2,311	8.9	7.0	7.5	14.8	11.4	9.5	5.7	65.0
y ² cv v B/bi ct ⁶ g ² bb ¹	2,368	6.9	6.9	7.3	13.8	10.1	8.6	7.2	60.9
Combined bb ¹ data	4,678	7.9	7.0	7.4	14.3	10.8	9.0	6.4	62.8
Standard map		6.9	6.8	7.3	13.0	11.4	12.6	9.0	66.0

The study of interchromosomal effects in crossing-over, carried out with Dr. Helen Redfield, has been extended to the second chromosome. A comparison of crossing-over in four classes of females obtained from the same set of cultures was made. In all four groups the second chromosome was marked throughout its length. One group had normal first and third chromosomes; two other groups contained inversions which eliminated

crossing-over almost completely in the first and in the third chromosomes; the last group carried both these inversions in the same female. The results were similar to those reported last year for the third chromosome. The suppression of crossing-over in either chromosome I or III, or in both, caused an increase in crossing-over in chromosome II, as in the table below.

Type of female	N	al-dp	dp-b	b-pr	pr-c	c-px	px-sp	Total
+/+; "all"/+; +/+	2894	10.3	27.7	3.5	16.2	20.0	3.5	80.2
CIB/+; "all"/+; +/+	1776	12.4	29.0	9.3	21.7	23.5	5.9	101.8
+/+; "all"/+; Payne/+	2519	14.2	29.7	5.8	18.9	25.3	6.0	99.9
CIB/+; "all"/+; Payne/+	1652	18.5	37.3	12.4	31.7	29.9	7.8	137.6

The changed crossover values are due largely to an increase in the proportion of multiple crossovers, hence to a decrease in interference between crossovers. As in the data for the third chromosome, regional differences in the intensity of the increase are manifested. These regional differences show suggestive similarities to those previously found in triploid crossing-over.

A new Plexate deficiency (Plexate²) includes the loci blistered and balloon but not the loci speck and lethal-ns which are included in Plexate. Px² apparently does not diminish crossing-over, even in the brown-speck and speck-blistered sections, and hence Px² can be used as an ordinary dominant in studies of normal linkage. Plexate can be used as a quadruple recessive for the loci sp, lns, bs and ba, the exaggeration effect aiding separations in the case of bs and ba. The character balloon is further improved by placing the flies at 18° C., instead of the usual 25° C., during pupal development.

Another probable deficiency in the right end-region of chromosome II is that of the brown locus in the mutant type brown⁵. This lethal allelomorph of brown was a constituent of a stock called "purpleoid-like" for which we are indebted to Dr. O. L. Mohr. The other constituent was another brown allelomorph (bw⁴) which is so slight that homozygous bw⁴ is wild-type, the bw⁴/bw⁵ compound being "purpleoid-like."

The studies of neutralization of the character and viability effects of deficiencies by an including or overlapping duplication and reciprocally the neutralization of the character and viability effects of a duplication by overlapping or included deficiencies have been greatly extended by use of Pale-duplication (PdN) and of the five deficiencies Pale-deficiency (PDY), Plexate (Px), Plexate² (Px²), Minute-l² (Ml²) and Minute-l (Ml). For the new data on viability, an improved standardized culture technique has been used throughout, and the effectiveness of the improvement may be judged from the fact that for the form PDY/+ PdN/PdN the viability coefficient (percentage survival as compared with wild-type sibs) calculated from the data of Muller and Settles was 7; from the data of Bridges 1928 was 34; and from the new standard 80 per cent. As seen in the accompanying table the homozygous deficiencies are raised from 0 viability to 75, 94 and 45 for the included deficiencies Px, Px² and Ml², but the form Ml/Ml PdN/+ is still a net deficiency for the arc-plexus region, and hence entirely lethal. The form PDY/+ PdN/PdN is raised from 80 to 92, 87, 96 and 82 per cent

by substitution of deficiencies for the + section. Homozygous P_{DN} is changed from 0 viability to 26, 14, 17 and 1 by addition of the deficiencies. When homozygous P_{DN} is combined with a homozygous included deficiency, the net effect is that of a homozygous duplication of lesser extent. The survival values for these net duplications were 3, 12, 24 and 0 when P_x, P_x², M¹² and M¹ were used to shorten the Pale-duplication. As seen in the lower part of the table the combination of two separate deficiencies has a greater neutralization effect on P_{DN} in viability than either has alone. That the 0 viability of homozygous Pale-duplication is not due to a net deficiency at the point of break is shown by the fact that the form M¹/P_{DY} P_{DN}/P_{DN} is not lethal but has the viability of 82.

Deficiency	Df/+ P _{DN} /+	Df/Df P _{DN} /+	Df/P _{DY} P _{DN} /P _{DN}	Df/+ P _{DN} /P _{DN}	Df/Df P _{DN} /P _{DN}
Plexate.....	89	75	92	26	3
Plexate ²	82	94	87	14	12
Minute-l ²	92	45	96	17	24
Minute-l....	81	0	82	1	0

	+/+ P _{DY} /+	P _x /P _x P _x /M ¹ ²	M ¹ ² /M ¹ ² M ¹ ² /M ¹	M ¹ /M ¹ M ¹ /P _x
P _{DN} /+.....	85 100	75 96	45 34	0 99
P _{DN} /P _{DN}	0 80	3 28	24 2	0 5

It has been suggested that the high frequency of "mutation" at the break-age points in translocations is due to the occurrence of losses at the time of translocation. If this were so, then the known deficiencies which are found in the progeny of x-rayed individuals, should, in many cases, be associated with translocations at whose breakage points they would be located. "Minutes," which are known to be deficiencies in many cases, were selected from an x-ray experiment involving 22,588 flies. Of 110 complete Minutes, and 21 mosaic Minutes, it was possible to test 45. None of these were associated with translocations, or so far as tested with inversions. It is clear that no association exists between the occurrence of Minutes and translocations. This may be used as evidence against the hypothesis that mutations at the breaks are deficiencies.

In this experiment, where sperm was irradiated, one out of every six of the autosomal Minutes was a mosaic. Patterson (1932) has shown for the X-chromosome that mosaics occur in one out of every five cases. The results for the X and the autosomes are of the same order of magnitude. This indicates that, if the chromosomes are already split in some of the sperm, the chromosomes of a given sperm-cell behave alike. The alternative—that the proportion of split chromosomes in sperm is the same for both X and autosomes—is unlikely, but not excluded.

Plum-2, a new member of the series of brown allelomorphs studied by Glass and van Atta, has been studied in collaboration with Dr. Th. Dobzhansky. The analysis gives another case of the correlation of a break at the brown locus with a dominant eye-color effect. There is also an associated mutation to "light." Both loci are at the ends of the inverted section of

Plum-2. The data are consistent with the hypothesis that the behavior of a gene is somehow related to its position in the chromosome (Sturtevant). Plum-1 and Plum-2 show variegation for light, brown and minus. This, and the dominant eye-color are suppressed by the presence of an extra Y-chromosome, like the unstable translocations of Gowen and Gay. Further analysis shows that the presence of a free extra short arm of the Y is sufficient for suppression.

It has been possible to correlate a variety of data on the eye-colors of *Drosophila* by grouping the mutants into three classes (Year Book No. 31, p. 307). It appears that this grouping also holds good, with few exceptions, for the effects of these genes on testis sheath and ocellar color. It follows that similar developmental reactions are concerned with the color in these three places.

A peculiar interaction effect between purpleoid and an intensifier in chromosome III ("purpleoider") results in death to the double homozygote, although each single homozygote heterozygous for the other is viable. Several tests have shown that the death of the double homozygote is a function of this specific interaction and is not due to associated lethals. The addition of Pale-duplication saves the life of the double homozygote and reverses the intensification of the eye-color.

The mutants of *D. melanogaster* have provided two new cases of sterility of hybrid types where each parental mutant race has normal fertility.

A study of triploid and intersex hybrids between *D. melanogaster* and *D. simulans* (Schultz and Dobzhansky, Jour. Exp. Zool., vol. 65) indicates that neither failure of chromosome conjugation nor an upset of the sex balance of the hybrids is responsible for their sterility. A plausible formal hypothesis involves the assumption of complementary dominant genes for sterility.

It is possible to study the effectiveness of any given section of chromosome in sex-determination by observing its effect on the sexual characteristics of intersexes. Dobzhansky and Schultz have now extended an earlier study, using duplications for all sections of the X-chromosome. Each of the duplications tested turns the intersexes toward the female, the change being on the whole proportional to the cytological length of the active X-chromosome. In the presence of sufficiently long duplications, intersexes breed as fertile females, and certain duplications produce intersexual characters in males. With these data on the distribution of sex factors in the X-chromosome, the demonstration is complete that its effect on the determination of sex is the resultant of the action of many genes scattered in all except the inert region.

Several series of experiments with pure carbon dioxide have been made to find whether such treatment increases the rate of mutation and, if so, whether the mutant types produced were specific. Since CO₂ accumulates to a considerable extent in ordinary cultures, it seemed worth while to see if there is any relation between this gas and mutation. In the first series, adult males and females were placed in a tube, through which CO₂ gas was passed. Within half a minute the flies fell down and became motionless. After 4, 6 and 8 hours they were removed. They slowly recovered after several hours and were mated after 24 hours. The treated males were mated to ClB females and the ClB daughters crossed to wild males of the same stock as those treated. The treated females were mated to y⁴ w^a Inversion males and

F₂ cultures raised. Pupæ and larvæ were treated 8 and 6 hours, respectively, and the emergent flies mated together. In none of the F₁ or F₂ cultures was there evidence of increased mutation rate in dominants, recessives or lethals. It was found that the original stock, and hence also the offspring of the treated flies, contained a sex-linked "rough-eye" and a "curvoid" wing, which is a poorly viable third-chromosome recessive.

The effect of a high temperature (35° to 37° C.) in increasing the rate of mutation has been reported. The possibility that the irregularities of the results might depend on the presence of carbon dioxide seemed worth testing. Some young flies were put into pure CO₂ for half an hour, and then, while still in the closed tube containing the gas, were placed in an incubator at a temperature of 35.5° and 36° C. After 8, 2½ and 2 hours the flies failed to recover, although control cultures of non-treated flies showed that this temperature does not kill them. One set, after half an hour in CO₂, was kept at 36° C. for 31 minutes. On recovery the flies were mated to normal females suitable for the tests. There were 4366 offspring, none of which were mutants. Two other experiments gave similar results. These three experiments, so far as they go, give no evidence that the double treatment was especially effective in producing mutants. Other experiments gave no lethal ratios out of 110 pairs of flies tested.

Needham, James G., New York State College of Agriculture at Cornell University, Ithaca, New York. *Research on the biology of mayflies.*

The work has progressed steadily and is well-nigh completed. A comprehensive volume on the biology of mayflies in general, including a monograph of the species in the North American fauna, will be ready for publication during the year. Neither of these fields has been covered hitherto, and the extended life history work is such as has not been done in any other country.

GENETICS

Babcock, E. B., University of California Agricultural Experiment Station, Berkeley, California. *Investigations in the genus Crepis*. (For previous reports see Year Books 25-31.)

These investigations comprise two principal phases, *viz*, taxonomic research and cytogenetic research on *Crepis* species, but the two phases are interrelated and have been supplemented by certain miscellaneous studies.

TAXONOMIC RESEARCH

For a statement of aims and methods see the preceding year's report. Work has proceeded along the lines described in the previous report with a definite goal always in view, *viz*, completion of a monograph of the genus which shall be based on results of both taxonomic and cytogenetic investigations. With the aid of evidence concerning chromosome number and morphology, the difficult problems involved in classifying *Crepis* species according to their natural relationships are gradually being cleared up. At the same time the work of writing descriptions and preparing illustrations is advancing. Descriptions of 60 species are completed and these include some of the largest and most difficult groups involving in some cases several subspecies and numerous variant forms. About 180 plates of drawings are completed, representing 160 of the ± 220 species in the genus. It is hoped that most of the remaining drawings and a large part of the unfinished descriptions can be completed during the present year.

CYTOGENETIC RESEARCH

Chromosomes of species—Comparative study of the chromosomes of about 100 species, or nearly half the species in the genus, has been completed and manuscript of a comprehensive report on this phase of the investigation is in preparation. This report will also serve as the basis for a portion of the monograph.

Interspecific hybrids—Cytogenetic study of the following interspecific hybrids is now under way: (1) *Crepis dioscoridis* and three related species by F. L. Smith; (2) *C. fætida* and three related species by Mrs. M. S. Cave; (3) *C. aspera* and two related species by C. Lagomarsino; (4) *C. canariensis* and three related species by J. A. Jenkins; (5) *C. bureniana* and three related species by C. F. Poole and D. R. Cameron; (6) *C. syriaca* and three related species by D. R. Cameron. These studies have already furnished valuable evidence bearing on taxonomic problems and further evidence of this nature will doubtless be forthcoming.

MISCELLANEOUS STUDIES

(1) *Crepis tenuifolia*, its natural methods of reproduction and variability in chromosome number, and the problem of its origin. Work has been carried on by Poole and Cameron and will be continued by the latter. Poole has proved that embryos are formed before anthesis, thus showing that at least some viable seeds are produced apomictically. It has also been found that forms of this species with 15 and 24 chromosomes, respectively, occur in

widely separated regions of Asia. Based on the chromosome morphology of *C. tenuifolia*, Babcock has proposed the hypothesis that this species originated as an amphidiploid hybrid between two 8-chromosome species. From a critical study of comparative gross morphology, the two putative parental species have been discovered, but as neither has thus far been obtained in living condition, their chromosome number and morphology are unknown. (2) *Pollen morphology* in *Crepis* species and its taxonomic value has been studied in a large number of species by Poole and Babcock and a report will be published later. (3) *Chromosome structure* in the premeiotic prophase in several species of *Crepis* is being studied by Dr. M. M. Richardson, who has succeeded in overcoming certain technical difficulties which have hampered this line of investigation in the past. She has already discovered facts of much interest to cytology and genetics, such as the pairing of homologous chromosomes without chiasma formation. She has found the same types of structure in certain prophase stages as those existing in maize and there is the added advantage of being able to work on species having only three or four pairs of chromosomes.

GEOLOGY

Campbell, Ian, and John H. Maxson, California Institute of Technology, Pasadena, California. *Geological studies of the Archean rocks at Grand Canyon.*

During the fall months of 1932, some six weeks were spent in the field, studying the more readily accessible Archean exposures along the Grand Canyon of the Colorado in the region between Salt Creek on the west and Lone Tree Canyon on the east.

In beginning the work it was felt that the difficulty of the terrane as well as the complexity of the rocks would make progress proportionately slow. Nevertheless, even the preliminary field studies have produced some interesting results. Thus, quite certain proof has been obtained of the heretofore only suspected sedimentary nature of at least the larger part of the Vishnu schist. The evidence is partly structural and partly petrological, and taken altogether constitutes convincing proof of the sedimentary nature of these earliest rocks. Further, there is some indication of their mode of deposition. It is believed that these sediments were dominantly sandy clays, accumulated as marine deposits in a shallow, subsiding geosyncline. Essentially they represent the neritic zone and may be compared to the sandy shales of the Belt series of the Northern Cordillera, or even—to bring the comparison closer—to the non-calcareous sediments of the overlying Grand Canyon series such as the Shinumo quartzite and the Hakatai shale.

The difference between the Archean rocks and the Proterozoic seems largely to be the difference in degree of metamorphism, and the greater evidence of igneous activity in the earlier era. To evaluate these metamorphic and igneous processes is one of the chief concerns of the present investigation. The evidence obtained seems to indicate that the tilting of the Archean sediments had been largely accomplished before any of the major granitic intrusions took place, since in their emplacement these have clearly been influenced by the earlier structure. The recrystallization of the sediments is another matter, however. To what degree this is to be attributed to the earlier orogenic forces, or to the later igneous forces, is still conjectural. The evidence in hand is conflicting on this point. Not unlikely the later type of metamorphism (*i.e.* contact) has been superimposed upon the earlier type (*i.e.* regional metamorphism), with a corresponding lessening of the chances of deciphering the first records.

In the course of the work, significant observations have been made on structure. It is plain that the trends and patterns developed in the Archean have exercised control upon features even in the present landscape and topography. Faulting (much of it perhaps pre-Unkar) has been found to be more common and on a larger scale than at first suspected.

An apparent diversity of igneous types present in the area studied has been recognized as due to the later "deuteric" alteration of certain portions of an originally rather uniform type. The discovery of an excellent exposure of the upper portions of a granite batholith on Phantom creek has led to establishing the "Phantom granite" as the type for the area. Evidence is

being accumulated on the complex phenomena of ptygmatic folding, igneous invasion, assimilation and replacement. Four new chemical analyses (the first recorded for these rocks) of important Archean types have been obtained and 100 thin sections have been prepared.

During the coming field season it is planned to extend the work to the more distant Archean exposures, particularly to the critical area in the vicinity of Hermit Creek, where igneous rocks of a different type and apparently different relationships occur. Until these other areas have been studied, it will be impossible to come to any general conclusions as to the fundamental nature of Archean structure.

In the laboratory, it is planned, besides the routine examination of thin sections and comparison of analyses, to initiate two new types of study, if conditions seem to warrant. The first contemplates a study of the accessory minerals of the igneous rocks, following the method of A. Brammall in England, with a view to obtaining more data on the intrusive relationships, time sequences and petrogenesis of these rocks. Another study, even more time-consuming than the first, and which therefore may not be undertaken in the immediate future, would involve taking oriented sections (following the method of Bruno Sander at Innsbruck) of the metamorphic rocks, and working out orientation diagrams for the minerals present with a view to obtaining more detailed information on the structure and its origin.

METEOROLOGY

Bjerknes, V., Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-31.)

The work on *Physical Hydrodynamics with applications to Meteorology*, the content of which formed the main subject of the last two annual reports, has appeared in the German edition at the beginning of 1933, and the French edition is expected to appear in a near future.

The most important scientific achievement of the current year is connected with the *theory of the tides*.

The serious incompleteness of the Laplacean theory is pointed out in chapter XI, section 122, of the above book, as mentioned in the last annual report. In order to arrive at a satisfactory theory of the tides, *viz*, to work out the theory by integration of the exact equations, the term representing the vertical acceleration must be retained. This may seem discouraging, as it was, in order to facilitate the integration that Laplace omitted this term, and even then the great mathematicians from Laplace to Poincaré have been able to proceed only by *approximate methods* of integration.

But now Professor Solberg has succeeded in showing that the original equations, in which no term is omitted, are capable of *exact integration* when the depth of the sea is given by certain laws, as function of the geographical latitude. This is new proof of a frequent experience in mathematical sciences: an *artificial* simplification of a problem often obscures, so that the natural lines of progress are not observed, while the *natural* limitation of the problem often leads to its solution.

The general tidal problem, together with a number of other problems on fluid motion of the rotating earth, have been reduced by Professor Solberg upon study of a differential equation which is intimately connected with indeterminate integrals of the type $\int_{\alpha}^x x^{\alpha}(1-x)^{\beta} e^{\gamma x} dx$. For α or β equal to 0 this expression reduces to the incomplete Γ -functions; for $\gamma = 0$ it can be expressed by the Gaussean hypergeometric functions, of which the Bessel-functions present themselves as certain special cases. The investigation is thus of a rather general character, and it will require time to explore the whole field. But this exploration will give the key to the solution of many problems, including the atmospheric wave-motions of the rotating earth, in a much broader scope than carried out in our recently published book.

An investigation of C. L. Godske forms a useful complement to the investigations of Professor Solberg. The aim of Godske's investigation is to clear up the role of the centrifugal forces in curved fluid currents. These centrifugal forces have played an always increasing part in our investigations (see previous reports), and for two reasons: (first) even currents called rectilinear will, in their ultimate minute structure, be curved when we approach molecular dimensions, and the centrifugal forces due to these curvatures may be the ultimate origin of the important phenomenon of turbulence;

(second) all great-scale fluid motions are curved currents, as a necessary consequence of the curvature and the rotation of the earth, and the corresponding centrifugal forces therefore present themselves as fundamental for the cyclonic and the tidal theories.

In order to get basic conditions, Mr. Godske starts with the circular vortex and supposes the fluid to be homogeneous and incompressible. He thus finds a number of known results by a new method, and in addition a series of new results, of which the following may be especially mentioned: a new elementary solution of the hydrodynamic equations, representing a steady state of circulation; and a new internal cellular wave-motion, which exists in a homogeneous and incompressible fluid, caused by a variable distribution of vorticity, and which is analogous to the known cellular wave-motion due to a variable distribution of density in a heterogeneous fluid.

Passing to the investigations along the empirical line, one important point is to be mentioned. The empirical results, gained especially by the Bergen Weather Service, have issued from an always detailed and systematic and rational *analysis of the weather chart*. The aim of this analysis is to arrive at a representation of the atmospheric situation which must fulfil the following conditions: to be in exact correlation with any reliable and representative observation from the hundreds of observing stations; and to be the logical consequence of the representation found at the previous epoch of observation.

These methods of analysis have originated to a great extent from personal intuition, gained by daily experience in the work of forecasting. But though unseen principles are more or less felt as the actual basis of the intuition, it has been very difficult to express a clear view of them and to formulate rules in words or to give a systematic description of the methods. We have, therefore, been able to spread these methods only by personal instruction, and this has very much retarded their acceptance by other meteorological institutes. However, great progress has been made by Dr. Bergeron. Returning to the problem over and over again, he has to a remarkable degree succeeded in making explicit the principles underlying the intuition, and thus arrived at clear rules which can be formulated in words and to a series of operations in which one step logically follows the other.

Several publications on the subject will soon follow from Dr. Bergeron.

NUTRITION

Mendel, L. B., and H. B. Vickery, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-31.)

For some time our program of nutrition studies has involved the role of the inorganic components—the so-called mineral nutrients—of the diet. The success of feeding experiments with “synthetic” rations has depended in no small measure on suitable supplies of inorganic salts. The mixtures used vary in different laboratories; and when adequate amounts are furnished along with otherwise suitable food components, comparable results seem to be attained with several of the now familiar artificial salt mixtures. Last year it was pointed out that an important goal of experimentation in this field of investigation is to devise dietary salt mixtures in which the essential elements are in the best relative proportions; the intake may then be considerably reduced. The criteria of success are by no means always to be detected in the more obvious aspects of growth and nutritive well-being. Two groups of animals may resemble each other very closely in appearance, external measurements and other physical phenomena; yet the respective bones may vary widely in chemical composition. For example, ten groups of rats, each including ten animals, were fed rations widely different with respect to the amount and character of the essential inorganic ingredients, but otherwise similar. The rate of growth was nevertheless almost identical (4.5 to 5.0 grams a day) during at least a month. The rats were killed when they attained 200 grams body weight. Data regarding the salt intake and the analyses of comparable bones in these animals of the same body weight and approximately the same age are shown in table A:

TABLE A

Group No.	Total salt intake per 100 grams food	Calcium intake	Ash of dry extracted bones
	<i>grams</i>	<i>grams</i>	<i>per cent</i>
1	2.28	0.41	47.4
2	2.24	0.85	54.3
3	3.28	0.87	56.2
4	2.48	1.42	56.7
5	2.67	1.22	53.9
6	2.48	1.37	57.1
7	4.56	1.33	59.0
8	3.15	1.48	59.2
9	5.28	1.64	62.3
10	11.28	3.78	62.9

If the consumption of any salt mixture which has proved to be satisfactory when fed in abundant measure is decreased, a level of intake is presently reached at which the relative shortage of one or more essential elements begins to manifest itself by disturbances in growth. The first obvious change

is usually a decrease in the comparative daily gains in weight. Changes in bone composition also are noted. For example, see table B.

TABLE B

Salt mixture in 100 grams diet	Rate of gain in body weight per day	Ash of dry extracted bones
<i>grams</i>	<i>grams</i>	<i>per cent</i>
4.0 Osborne-Mendel.....	4.5	62.3
3.28 Osborne-Mendel.....	4.6	59.0
2.0 Osborne-Mendel.....	4.3	56.2
1.0 Osborne-Mendel.....	4.5	47.4
0.5 Osborne-Mendel.....	3.2	45.3
0.0 Osborne-Mendel.....	0.5	24.4

Comparisons of a series of different widely used salt mixtures have shown noteworthy inequalities of relative nutritive values, particularly with respect to the composition of the bones, when the inorganic ingredients in otherwise identical rations were offered at a sub-optimal (0.5 per cent) intake level. (See table C.)

TABLE C

Salt mixture in 100 grams diet	Rate of gain per day	Final body weight	Total amount Ca eaten	Ca : P ratio in diet	Ash in dry extracted bones
<i>grams</i>	<i>grams</i>	<i>grams</i>	<i>grams</i>		<i>per cent</i>
0.5 Osborne-Mendel.....	3.2	201	0.27	1:3.9	45.3
0.5 Sure's.....	1.2	149	0.33	1:4.8	41.7
0.5 Steenbock's.....	0.6	110	0.26	1:5.3	34.9
0.5 McCollum's.....	1.0	130	0.22	1:5.2	33.2
10 Osborne-Mendel.....	4.5	200	3.78	1:0.8	62.9
10 Sure's.....	3.1	200	3.62	1:1.8	62.8
10 Steenbock's.....	4.1	200	2.56	1:1.8	61.4
10 McCollum's.....	3.0	200	2.56	1:1.8	61.7

All of these salt mixtures are greatly improved at the low level of intake when additional calcium is supplied. A relative proportionate deficiency of this element in all of the mixtures studied is thereby indicated. The comparative need of phosphorus was not investigated in this series of tests because an abundance was furnished by the food protein (casein) and by the vitamin supplement (yeast). An illustration of the advantage of larger proportions of calcium in the salt mixture is given by records of comparative experiments in which calcium was added so as to make the intake thereof equal to that supplied by considerably larger intakes of the unsupplemented respective salt mixture. The results are shown in table D.

It appears from these data that liberal supplements of calcium alone may permit vigorous growth and greatly improved mineralization of the bones when the rest of the inorganic elements are supplied at comparatively low levels of intake. However, inasmuch as even greater deposition of salts in the bones is secured with higher levels of the unsupplemented salt mixtures

TABLE D

Salt mixture in 100 grams diet	Supplement per 100 grams diet	Average daily gain in body weight to 200 grams	Calcium content of 100 grams diet	Ash of dry extracted femurs
<i>grams</i>	<i>grams</i>	<i>grams</i>	<i>grams</i>	<i>per cent</i>
0.0	0.0	0.5	0.02	24.4
0.5 Osborne-Mendel.....	0.0	3.2	0.08	45.3
0.5 Osborne-Mendel.....	0.45 CaCl ₂	3.9	0.24	52.2
0.5 Osborne-Mendel.....	0.43 CaCO ₃	3.6	0.25	55.6
2.0 Osborne-Mendel.....	0.0	4.3	0.25	56.2
0.5 Sure's.....	0.51 CaCl ₂	3.8	0.25	52.4
0.5 Sure's.....	0.46 CaCO ₃	4.2	0.25	54.3
0.5 Osborne-Mendel.....	0.7 CaCO ₃	4.6	0.38	56.4
3.28 Osborne-Mendel.....	0.0	4.6	0.38	59.0
1.0 Osborne-Mendel.....	0.8 CaCO ₃	5.2	0.46	59.2
4.0 Osborne-Mendel.....	0.0	4.5	0.46	62.3

(without any larger daily absolute intake of calcium) some element other than calcium seems also to be requisite in larger proportions. Supplementation of the Osborne-Mendel salt mixture with magnesium, sodium, chlorine, sulfur, iron and aluminium in individual tests has not resulted in any significant improvement.

Attempts were made to supply the calcium supplements in different combinations. Calcium carbonate was found to be more effective than an equivalent amount of calcium chloride. This difference is probably not due to the circumstance that one of the added compounds is potentially alkaline whereas the other is potentially acid. Tests in which two different salt mixtures were fed at a 0.5 per cent level resulted in poorer mineralization of the femurs whenever small supplements of sodium chloride were used.

When rats are maintained for some time on different salt mixtures at a low level (0.5 per cent) of intake and are thereafter given either adequate daily amounts (4 per cent) of the mixture of mineral nutrients, or else a supplement of calcium equivalent to the calcium in the mixture when fed at this level, the calcification of the bones improves rapidly. However, even after 60 days of the improved dietary regimen the ash content of the femurs had not quite attained that of the bones of control animals of the same age that had continuously subsisted on the adequate food mixture.

The "fat" content of the bones of rats that have been maintained on the low (0.5 per cent) levels of salt intake has been surprisingly high and is not readily restored to the normal proportion when the dietary regimen is rendered adequate with respect to mineral ingredients, as shown in table E.

The character and significance of the observed changes in the "fat" of the bones deserve further consideration.

Inasmuch as most so-called "synthetic" food mixtures involve the use of the phosphoprotein casein, we have replaced it with edestin, in a series of tests of our salt mixtures. This eliminated the organic phosphorus of the protein. Under otherwise comparable conditions, the degree of calcification of the bones was identical, regardless of the protein used.

TABLE E

Salt mixture in 100 grams diet	Duration of feeding	Duration of supplemental feeding	Composition of bone		Ash of dry extracted bones
			Water	Fat	
<i>grams</i>	<i>days</i>	<i>days</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
0.5 McCollum's.....	90	0	55.4	21.8	44.5
0.5 Sure's +0.28 NaCl.....	90	0	57.8	21.1	42.2
0.5 McCollum's.....	60				
0.5 McCollum's +1 CaCO ₃		30	43.3	14.6	59.0
0.5 Sure's +0.28 NaCl.....	60				
4.0 Osborne-Mendel.....		30	42.5	11.7	60.9
0.5 McCollum's.....	60				
0.5 McCollum's +1 CaCO ₃		60	35.8	10.0	63.6
0.5 Sure's +0.28 NaCl.....	60				
4.0 Osborne-Mendel.....		60	35.4	9.0	64.1
0.5 McCollum's +1 CaCO ₃	90	0	34.9	4.0	65.2
4.0 Osborne-Mendel.....	90	0	33.5	5.9	66.2
0.5 McCollum's +1 CaCO ₃	120	0	33.1	4.2	66.6
4.0 Osborne-Mendel.....	120	0	32.5	6.6	66.8

Several anatomical and physiological abnormalities have been observed incidentally in some of the rats subsisting at low intakes (0.5 per cent) of the sale mixtures. They include symmetrical depilation on the rump areas, prominence of the eyeballs and related ocular disturbances, changes in the shapes of parts of the skeleton, "screaming fits." All of the animals examined show some degree of anemia (low hemoglobin content).

Certain investigators have expressed the belief that characteristic symptoms of avitaminosis due to lack of vitamin A can be averted or relieved by administration of iodine and of iron, together with reputedly essential fatty acids. Resumption of growth and cure of xerophthalmia have actually been reported as a result of supplying ferrous iodide and linoleic acid; and the outcome has been interpreted to indicate mobilization of the vitamin stores in the body as well as an actual substitution for vitamin A. This obviously has a significant bearing on the nature and function of vitamin A—a topic long under consideration by us. We therefore undertook experiments intended to throw light upon the conjectures. Our tests failed to confirm them. The administration of ferrous iodide and linoleic acid, alone and in combination, was ineffective as a cure for xerophthalmia, as a stimulant to growth, or as a preventive of infection or renal disturbance in rats deprived of vitamin A. This is in harmony with the negative results of other recent investigators.

In an earlier report, reference was made to the studies undertaken in cooperation with Dr. Francis G. Benedict of the Nutrition Laboratory of the Carnegie Institution of Washington in Boston on the metabolism of the rat. Some of the results, dealing with technique and basal metabolic rate measurements, have already been published. Papers dealing with the effects of some

external factors upon the metabolism of the rat, and with the influence of previous exercise upon the metabolism, the rectal temperature, and the body composition of the rat, are now ready for publication. The details have been dealt with in Dr. Benedict's reports.

Continued studies of the vitamin potency formerly designated as due to vitamin B and subsequently demonstrated to include at least two separate factors, B (B_1) and G (B_2), have furnished some information in regard to the antianemic factors now known to be present in liver. Recently it has been ascertained that parts of the stomach also promote the cure of pernicious anemia; and mixtures of hepatic and gastric products are stated to be decidedly more potent than equivalent quantities of the liver and stomach tissues from which they are prepared. It has been alleged that vitamin G may play a role in this augmentation of antianemic effects. Assays of a number of representative antianemic products now available commercially have indicated that there is no parallelism between the vitamin G concentration and the antianemic potency. The tests were made by Dr. Block, Research Fellow in Yale University, and Dr. Farquhar, on rats fed the following basal ration that is believed to exclude vitamin G, although it supplies all other nutritional essentials:

	<i>per cent</i>
Casein (extracted)	22.0
Crisco	24.9
Linoleic acid	0.1
Osborne-Mendel salts + Cu + Mn	4.0
Sucrose	48.9
Cystine	0.1

The animals received distilled water *ad libitum*; also an adequate dose daily of a specially prepared concentrate from rice polish to supply vitamin B. Each week they were given 1 drop of a concentrated preparation that furnished adequate amounts of vitamins A and D. On this ration young rats quite promptly fail to grow. The tests were conducted as curative experiments in which definite doses of the substances to be assayed were supplied each day. The average daily gains in weight over a period of 30 days afforded the comparisons of potency. Illustrative results are shown in table F.

TABLE F

Product used	Dosage per day	Average daily gain in body weight of rat
	<i>milligrams</i>	<i>grams</i>
I. Lilly's No. 343	40	2.9
	80	4.0
	160	4.4
II. Ditto, treated with human gastric juice	40	3.1
III. "Extralin"—a liver extract treated with gastric scrapings of the pig	40	2.9
	160	4.9

According to clinical reports, products II and III should be far more potent as antianemic agents than the widely used product I. Indeed, product III

is reported to be three to four times as potent as I. Nevertheless a comparison of the vitamin G assays shows almost identical potencies of all the substances. It seems unlikely therefore that any change of the original products resulting in greater antianemic properties involves augmentation (or decrement) of their content of vitamin G.

Incidentally, it has been observed by Dr. Block and Dr. Farquhar that, *in the absence of water*, baker's yeast may be heated to 95–100° C. for periods 2 to 4 weeks without material loss of vitamin G. In tests of the sort described above and with a daily yeast dosage equivalent to 400 milligrams, the results were as shown in table G.

TABLE G

Yeast	Average daily gain in body weight
	<i>grams</i>
Unheated.....	5.3
Heated 2 weeks.....	4.7
Heated 4 weeks.....	5.5

The investigation of the reproduction of the albino rat on an apparently adequate ration has been continued by Professors Arthur H. Smith and W. E. Anderson of the Department of Physiological Chemistry, Yale University, as outlined in previous reports. On the basis of the data available for the first, second and third generations, an inquiry has been made into the relationship of the interval between pregnancies to the number and size of litters and to the vigor of the young at weaning. The evidence concerning the average percentage of fertile matings and the average number of young born per litter does not at present warrant a conclusion relative to the influence of the interval between pregnancies in this connection. On the other hand, there appears to be a decreased average percentage of young weaned in successive generations; this observation may indicate a deficient lactation.

In all groups the weights of the young at weaning have been uniformly maintained at a level varying from 40 to 47 grams. Inasmuch as the data pertaining to somewhat over four thousand rats of both sexes are included in this value, it appears that the present investigation represents a record of unusual success in reproduction of the albino rat; this result can be attributed in no small degree to favorable nutrition.

The results of our study of the nutritive properties of tobacco seed were given in detail in last year's report. These, together with a description of the globulin of the seed and of an analysis of the hot-water extract of the fat-free seed, have now been published as a Bulletin from the Connecticut Agricultural Experiment Station. The analysis of the extract was so incomplete that we have felt it desirable to continue the investigation. Results have been secured that confirm those previously obtained with respect to the qualitative make-up of the extract, but appreciably larger proportions of certain components have been isolated. This applies particularly to the proportion of allantoin. The difficulty of dealing with the individual components of such extracts has compelled us to be satisfied in many cases with

an allocation of the nitrogen into the various groupings for which indirect methods of analysis have been developed. Although it is thus frequently possible to account for a large proportion of the nitrogen of the several fractions, such an expedient is thoroughly unsatisfactory from the standpoint of the student of nitrogen metabolism. It is highly desirable that both the qualitative and, to a considerable extent, the quantitative composition be obtained in order that an accurate picture may later be drawn of the chemical changes that accompany the development of the organism.

Dr. A. White, who has spent the past year in our laboratory during his tenure of the Porter Fellowship of the American Physiological Society, has completed the development of the cuprous mercaptide method for the determination of cystine and has employed it in the study of a considerable number of proteins. The outlines of the method were mentioned in last year's report. The results of the analyses agree closely with those obtained by Folin and Marenzi, and by Sullivan, with their respective colorimetric methods, and by Sullivan with the Okuda iodine titration method. Support is thereby lent to the view that these methods, when properly conducted, yield trustworthy results. The nature of the precipitate that appears when cuprous oxide is added to a dilute sulfuric acid solution of cysteine has also been investigated, and analytical results have been secured that indicate the compound to be best represented by the formula $C_3H_6O_2NSCu \cdot CuSO_4 \cdot 2H_2O$. The precipitate changes in composition, however, when the supernatant fluid is neutralized to Congo paper; the fundamental compound in the precipitate appears then to be the cuprous salt of cysteine cuprous mercaptide, $C_3H_5O_2NSCu_2$.

Attempts to recover cystine from the cysteine mercaptide showed that, during precipitation or subsequent decomposition with hydrogen sulfide, traces of ammonia and probably also of pyruvic acid were formed; furthermore, colorimetric measurements of the cystine liberated were invariably low. It was shown conclusively that the organic sulfur of the precipitate is a quantitative measure of the cystine originally taken but, obviously, a small part of the cystine is converted into other substances during the treatment.

Dr. W. G. Gordon of the Department of Physiological Chemistry, Yale University, has continued his studies of the complex compounds of amino acids with mercuric chloride. Complexes of glycine, alanine, phenylalanine, leucine, lysine and glutamic acid were prepared by precipitation with barium hydroxide, and also in many cases with sodium, potassium or lithium hydroxide. With the exception of the complex of lysine, all of these compounds contained mercury and nitrogen in the atomic ratio of 2:3. All contained at least one equivalent of chlorine and all, save lysine, from one-half to one equivalent of alkali metal. Attempts to separate glycine from alanine, and phenylalanine from leucine, through the agency of the complex mercury compounds, were unavailing, owing to the co-precipitation of alanine with glycine and of leucine with the phenylalanine. Although alanine and leucine both form water-soluble complexes in the presence of mercuric chloride and barium hydroxide under conditions in which glycine and phe-

nylalanine are completely precipitated, the separation of the respective pairs of amino acids in this way is impossible.

The complex compound of alanine and mercuric chloride precipitated from diluted alcohol by potassium hydroxide is soluble in water after being dried. The bacteriostatic and toxic properties of this substance have been investigated in a preliminary way. It was found to have approximately the same toxicity as mercuric chloride, but it does not precipitate protein under the conditions of the test; possible medicinal value is thereby indicated.

A study of the metabolism of the nitrogenous compounds and of the reducing compounds, during the early stages of curing and also during the culture of mature tobacco leaves in water, has been completed. A report of the results has been submitted to the Institution for publication and is now in press. Many of the newer findings confirm the tentative conclusions of a previous investigation of the curing of tobacco. The most important of these show that during curing, nitrate is synthesized in the detached leaves in considerable amounts, the quantity of nicotine at first increases slightly and then diminishes, the protein of the leaves is rapidly digested to amino acids, and a considerable proportion of the amino nitrogen so produced is converted into amide nitrogen. Somewhat more than a fifth of the organic solids of the leaves are metabolized into volatile products, but only a small part of this loss can be accounted for in terms of reducing carbohydrates.

The leaves that were subjected to water-culture gave evidence of an extremely rapid synthesis of nitrates, a slow continuous loss of nicotine, an extensive digestion of the protein to amino acids and a conversion of much of the amino nitrogen to amide nitrogen. In the later stages of the culture, reduction of most of the newly formed nitrate, apparently to ammonia, took place. The total metabolism, as measured by the loss of organic solids from the tissues, was materially greater than that observed during a similar period of curing. Evidence was found that, during the early stages of water culture, carbohydrate is metabolized in preference to protein.

From a comparison of the behavior of these two lots of leaves it was possible to draw certain inferences with regard to the behavior of normal intact mature leaves. It would appear that the digestion of protein in the intact leaf is very slow although a mechanism for rapid digestion is present. The reducing carbohydrates, on the other hand, are oxidized with considerable velocity. There appears to be a sensitive equilibrium in the intact leaf between nitrates and the products of their reduction which can be displaced in either direction. Nicotine enters the metabolism to a small but definite degree. The synthesis of amides does not seem to be an active function of the intact leaf, although a mechanism is present whereby ammonia can be rapidly and efficiently converted into amides should conditions arise under which ammonia would otherwise accumulate.

Extensive studies of the acids of tobacco leaf have been carried on throughout the year by Dr. G. W. Pucher of the Connecticut Agricultural Experiment Station staff who is attached to our laboratory. We referred last year to the development of a method to determine nitric acid by means of ether extraction of samples of leaf tissue that previously had been

acidified with sulfuric acid. A similar technique has now been applied to the determination of malic, citric, and oxalic acids, and also to the estimation of the total organic acids of the leaf. These methods have been employed in a study of the metabolism of the organic acids during the curing operation, and the accuracy of the results has been confirmed by the ester distillation method. It was found that malic acid diminishes somewhat in amount and that oxalic acid changes very little during curing. There is an enormous increase of citric acid, the quantity in fully cured leaves being about six times greater than that in the green leaves before these are cured. Notwithstanding the increase in citric acid, the total acidity of the leaves changes little owing to a corresponding decrease in the quantity of unknown acids present; curing therefore gives rise to a material simplification of the organic acid picture. A full discussion of these results has been embodied in a Bulletin from the Connecticut Agricultural Experiment Station now in press.

Several of the methods developed in this laboratory for the analysis of various forms of nitrogen in leaf tissue have been studied in cooperation with the Association of Official Agricultural Chemists. The results of referee work on the methods for nitrate nitrogen and ammonia nitrogen have been published, and further work on the new method for nitrate nitrogen is in progress.

Owing to the construction of a new building at the Experiment Station, our laboratory has been able to expand into quarters previously occupied by other departments. The former badly overcrowded conditions for our work have thereby been greatly relieved.

The following have served as assistants in the work: Alfred J. Wakeman, Ph.D.; Charles S. Leavenworth, Ph.B.; Lucille Reed Farquhar, Ph.D.; Laurence S. Nolan, technician; Luva Francis, secretary.

Sherman, H. C., Columbia University, New York, New York. *Relation of food to length of life.*

Previous investigations in the Department of Chemistry of Columbia University have shown that, starting with an already adequate diet and normal condition of nutrition, an increase of about 10 per cent in the average length of life of adult experimental animals was induced by an alteration of the quantitative proportions of the ingredients of the food-mixture. If the infant mortalities were also included in the average, the increased length of life resulting from the improvement of the food supply would be still more pronounced.

While the possibility of reducing the death rate of the young by the feeding of better-balanced diets, even when no actual dietary deficiency disease is involved, has probably been little doubted in recent years, the fact that food adjustments may similarly improve the average length of life of normally nourished adults is a newer finding. It is with the further development of this finding that the present research is concerned.

At the time of writing (August 1933), rat families in this laboratory are thriving in the thirty-fourth generation on a diet consisting of five-sixths ground whole wheat and one-sixth dried whole milk, with table salt and

distilled water. This would seem to be sufficient evidence that this diet (Diet A) is adequate, as the term adequate is ordinarily used and understood.

This normal nutritional condition is, however, capable of improvement. When the proportion of dried whole milk in the wheat-and-milk mixture was increased (from the original one-sixth) to one-third (Diet B), there resulted better growth, lower death rates and other evidences of higher vitality in all stages of the life cycle, and (as noted above) an improvement of about 10 per cent in the adult life-expectation.

It seems appropriate to note briefly the relation of these findings to the question whether rapid growth is consistent with longevity. In the present investigation we are not dealing with any such extremely forced growth as has sometimes been obtained in laboratory experimentation and is also sometimes practiced in the rearing of farm animals. The differences in growth rates with which the present research is concerned are such as lie within the rather wide zone of what would ordinarily be considered normal. Similarly, we are not here concerned with cases of extreme longevity, but rather with the problem of the extension of the normal average life cycle—again using these terms as ordinarily employed and understood. Thus the laboratory finding already mentioned may be said to correspond to the improvement of the current human adult life expectation of 70 years to 77 years instead—a significant influence of the food upon the average length of normal life, not a study of exceptional cases of extreme old age.

Within the range of the present investigation, then, both more rapid growth and a significant extension of the average length of life were induced in the same individuals by the same improvement of a dietary already adequate.

Thus in the completed series of experiments above mentioned in which each sex was found to live 10 per cent longer on Diet B than on Diet A, the life histories show that these identical animals had in the period of most rapid growth exhibited female growth rates about 30 per cent and male growth rates about 40 per cent higher as a result of this same difference in diet. That these differences were certainly due to the food was assured by the identity of hereditary and other conditions and is further shown by the fact that the differences in length of life which appeared among the individuals of the same sex *on the same diet* did not show correlation with their rates of growth in early life. As between the sexes, however, females grow more slowly and live longer than males.

The significance of the differences induced by the improvement in food are strongly supported by statistical analysis of the data. The large number of data, especially for early growth, which our records now include, afford the basis for a further consideration of the validity of the statistical interpretation. This is being treated in a paper which we are now preparing for publication.

The further development of our study of the relation of food to length of life presents three aspects: (1) attempts to ascertain just what chemical elements and compounds are concerned in such extension of the average length of life as was induced in the experiments above noted; (2) investigation as to the practicability of further extension of the average life-cycle or adult life-expectation by further chemical improvement in the already

adequate food supply; (3) experiments of similar character with diets in which the articles of food are more varied and are used in proportions more directly modeled upon ordinary human food supplies.

One series of experiments upon the first aspect of the research is now so well advanced that tentative results should be in hand within the coming year, though larger numbers of such experiments may prove necessary for conclusive establishment of the findings.

The greater part of the aid afforded by the grant received from the Carnegie Corporation of New York through the Carnegie Institution of Washington during the period covered by this report has been devoted to experiments upon the second aspect of the research, in the hope of ascertaining whether further increase of the average length of life can be induced by further improvement in the better of the two diets hitherto extensively studied, and, if so, whether here also increased length of life will prove consistent with full maintenance of the evidences of positive health throughout the life cycle. These experiments are now necessarily in their earlier stages. The indications thus far are distinctly gratifying. From two to three years more will be required for the completion of the normal life cycles of these animals.

In the third aspect of this research, the elaboration of experimental diets planned in direct imitation of the human food supply, only exploratory work can be undertaken as long as our means are so completely absorbed in the experiments described in the preceding paragraphs.

The efficient collaboration of those who have shared in this work, whether as research assistants or as volunteers, is gratefully acknowledged.

While some of the work now in hand continues experiments which were already in progress, the new experiments which have been begun by aid of the funds administered through the Institution have been planned under the great advantage of the advice of Dr. F. G. Benedict and with a view to providing the most favorable material for direct experimental coordination of these studies of the relation of food to length of life with his comprehensive investigation of the physiology of advancing age.

Williams, R. R., and Walter H. Eddy, Teachers College, Columbia University, New York, N. Y. *Physiological properties of the vitamins*. (For previous reports see Year Books Nos. 27, 29–31.)

Our study, which is carried on under a grant of funds from the Carnegie Corporation of New York to the Carnegie Institution of Washington, has continued through the year to have as its main objective the isolation of vitamin B₁ in quantity.

Further partial confirmation has recently been afforded in other laboratories of the previously reported isolations of this substance by Jansen in 1926 and by Windaus in 1931. Seidell and Smith¹ isolated the compound early this year from brewers' yeast in the form of the picrolonate, and Kinnersley, O'Brien and Peters² have also obtained it in the form of the hydrochloride from bakers' yeast.

¹ A. Seidell, and M. I. Smith. Jour. Amer. Chem. Soc., vol. 55, 3380, 1933.

² W. K. Kinnersley, J. R. O'Brien, and R. A. Peters, Biochem. Jour., vol. 27, 232, 1933.

Jansen¹ has endeavored with some success to reconcile the ultimate analyses of several previous workers as supporting the empirical formula $C_{12}H_{18}O_2N_4S \cdot 2 HCl$. However, Peters *et al.*² report that their hydrochloride has a higher activity per unit weight than the isolated products of Jansen and Windaus, although they believe the physical criteria of their product to be indicative of a still impure state. Peters expresses the opinion that all of the supposedly completely isolated substances reported by the various workers owe their activity to residual impurities rather than to the principal component. However, we emphatically prefer to reserve judgment on this point as the supposed higher activity of Peters' product is almost, if not quite, within the limit of experimental error in animal testing. We regard it as peculiarly unfortunate that Peters did not administer the preparations under comparison in exactly equal doses. The minimum dose given of Windaus's product was 0.014 mg.; of Jansen's 0.022 mg.; of Peters' 0.009 mg. On account of inequality of dosage, the evidence of differences in activity rests wholly on the arithmetical process of dividing the dose administered by the number of days elapsing after cure before recurrence of symptoms. While this process is probably valid within limits, it can not be valid in extreme cases; otherwise the administration of a single large dose would protect indefinitely against recurrence of symptoms, which we know is not the case. We have a paper in course of preparation which will deal with the "day dose" principle and the correlation of results with different test methods and test animals.

The yields of vitamin by Peters's process as well as Seidell's are small. Peters obtains 15 to 20 mgs. from 50 kilos of bakers' yeast. The yeast is presumably moist, which would make the yield about 50 mgs. from 50 kilos of dry material. Seidell does not state his yield directly, but one infers from his various papers that it is 80 to 100 mgs. calculated as hydrochloride from 50 kilos of dry brewers' yeast. The best previously reported yield was that of Van Veen³ in 1931, who worked with rice polish to obtain the equivalent of about 65 mgs. of not yet quite fully purified hydrochloride from 50 kilos of rice polish. Although no previous worker appears to recognize it fully, we are convinced that in all these cases major losses occurred very early in the process and more specifically in the removal of activity from the initial adsorbent (fullers earth, except in the instance of Peters, who used activated charcoal as an adsorbent). Not only have we invariably experienced large losses when extracting fullers earth with baryta, but we have also satisfied ourselves by experiments to be detailed elsewhere that fullers earth will adsorb large quantities of vitamin from extracts made strongly alkaline with baryta, and that therefore the complete removal of vitamin from fullers earth by baryta is unattainable. The crudities of animal testing are doubtless responsible for other workers overlooking these large losses, which probably usually approximate half the vitamin present.

By the use of our process of extracting the vitamin from fullers earth with acid quinine sulphate solution, followed by clearing operations with baryta

¹ Rec. Trav. Chim. d. Pays Bas, vol. 52, 366, 1933.

² W. K. Kinneresley, J. R. O'Brien, and R. A. Peters, Biochem. Jour., vol. 27, 232, 1933.

³ A. G. Van Veen, Rec. Trav. Chim. d. Pays Bas, vol. 50, 610, 1931.

and thereafter with helianthin, we obtain a solution from which the vitamin is largely precipitated by means of silver nitrate at pH 4.5 to 7.5, after the manner of Jansen and Donath. The silver precipitate is decomposed with hydrochloric acid and the resulting solution is benzoylated in the presence of an excess of sodium bicarbonate. After removing the benzoylated by-products, the solution is acidified and precipitated with phosphotungstic acid at pH 5-1. This precipitate is refractionated by the use of purified phosphotungstic acid, clarified by the use of alcohol and finally precipitated with gold chloride, following in these steps Peters' recent procedure. The gold precipitate is decomposed with freshly precipitated silver¹ and the resulting solution is evaporated to dryness and taken up in strong alcohol. By layering with petroleum ether, crystallization of the hydrochloride is induced in the form of rosettes of needles, or crystallization may take place directly from the alcoholic solution as plates.

Needle crystals have also been obtained by the above process, omitting the benzoylation step. In one instance, we have omitted the gold chloride precipitation also. In another instance in which both benzoylation and gold precipitation were omitted, an additional refractionation with phosphotungstic acid was inserted in the Peters's procedure. All these variations yield crystals, but it will require some experience to determine which produces the best yield. The omission of the purification steps in question prolongs and complicates the final fractional crystallization somewhat. Therefore, for the present we are using the full procedure above described. Various precautions are observed in the several steps. These will be described in later publications. The following yields have been obtained:

Exp. No.	Kilos rice polish used	Yield of crystals mgs.	Calc. yield per 50 kilos polish
1920	4.4	8.4	95
1944	18.8	77.4	206
1950	37.6	187.0	249
2011	101.8	525.0	257

With further experience we are still finding it possible to improve yields somewhat. Our best results correspond to 250 to 300 mgs. of hydrochloride from 50 kilos of rice polish. This represents about five fold the amount obtained by Peters from an equal weight of bakers' yeast and about fifteen fold the yield originally obtained by Jansen and Donath from rice polish. The melting point of the hydrochloride after one recrystallization ranges from 247° to 251° C. corrected.

We have been guided in our experimental work by curative tests on rats according to M. I. Smith.² Our tests with the crystalline material (without recrystallization) are shown in the following table.

¹ H. W. Dudley, *Biochem. Jour.*, vol. 23, 1064, 1929.

² U. S. Pub. Health Reports, vol. 45, 116, 1930.

Exp. No.	Rat	Dose	Result	Duration of cure
	No.	Mgs.		Days
1920	18973	0.00375	Improvement	0
	19089	0.00375	Cured	10
	18242	0.00375	Improvement	0
	18992	0.0050	Cured	9
	19092	0.0050	Cured	8
	18947	0.0050	Cured	9
	18962	0.0075	Cured	9
	18974	0.0100	Cured	12
1944	19092	0.00375	Improvement	0
	19089	0.00375	Cured	6
	19005	0.0050	Improvement	0
	19457	0.0050	Cured	8
	18568	0.0050	Cured	7
	19092	0.0070	Cured	8

It is somewhat difficult to compare these results directly with those of European workers on account of our use of rats rather than pigeons. Our best resort would appear to be the results of Seidell and Smith¹ who report an experimental comparison of crystals of the hydrochloride furnished them respectively by Jansen, Windaus and Peters. According to these tests "the minimum curative dose for these varied between 0.008 and 0.012 mg.," using the rat with a technique essentially the same as our own. Seidell and Smith consider that the minimum curative dose of their picrolonate of 0.015 mg. corresponding to 0.008 mg. of the hydrochloride represents as high a purity as has been so far attained. However, Windaus finds 0.0055 mgs. of hydrochloride curative for pigeons and our experience indicates that the rat and pigeon have nearly the same vitamin requirement without correction for difference in body weight. While it seems evident from our tests above reported that our crystalline product is at least as active as those of other workers, we do not at the present moment wish to attach significance to the cures which we obtained with lower doses on account of the variations of testing technique and of individual judgment as to condition of animals.

The early steps in our process have been carried out repeatedly on a large scale according to a factory type of operation. The later steps have been practiced as yet only on a much smaller scale in order to conserve material until proper experience has been acquired to indicate the most suitable procedure and equipment. It is felt that the vitamin must be made available in quantities of several grams in order to permit full confirmation of purity and to progress in constitutional studies.

A paper regarding our isolation procedure and yields is being presented at the annual meeting of the American Chemical Society in September 1933.

We have continued to enjoy the effective cooperation and assistance during the year of Marion Ammerman, John C. Keresztesy and Robert E. Waterman, who have performed a large part of the experimental work.

¹ *Loc. cit.*

PALÆONTOLOGY

Merriam, John C., and Associates. *Continuation of palæontological researches.* (For previous reports see Year Books Nos. 20-31.)

The presence of a large group of foreign geologists and palæontologists in America at the time of the International Geological Congress gave opportunity for conference with leading investigators on a number of critical problems on which research is being conducted by the Carnegie Institution of Washington. Two of the visitors to America, who came in part as guests of the Carnegie Institution, were specially helpful with advice regarding investigations under way.

Sir Arthur Smith Woodward, of England, one of the leading students of the world on problems relating to occurrence and characteristics of early man, presented one of the most important papers on the study of early man in America, read before the International Geological Congress, and was able also to visit field excavations in New Mexico representing some of the outstanding researches of the year concerning occurrence of early man. It had been the privilege of the Institution to cooperate in some measure with the Philadelphia Academy of Sciences and the University of Pennsylvania in connection with excavation work at Clovis, New Mexico, where artifacts were reported in association with remains representing an extinct fauna. The studies in New Mexico were carried on under the supervision of Mr. Edgar B. Howard, whose recent contributions in this subject have been of exceptional interest. Through support of the Carnegie Institution of Washington, excavation for the purpose of securing information regarding the faunas represented at Clovis was conducted by Dr. Chester Stock, of the California Institute of Technology, in cooperation with Mr. Howard. It was the privilege of Mr. Merriam to examine the excavations in the early summer and to visit the site again with Sir Arthur and Lady Smith Woodward, Dr. Victor van Straelen of the Musée Royal d'Histoire Naturelle in Brussels, Dr. Chester Stock and Mr. Edgar B. Howard in the first days of August.

On occasion of the visit in August, it was possible to see in Mr. Howard's excavations several localities at which all of the observers were in agreement regarding association of highly developed artifacts with bones of a large elephant and other mammals. While other association of artifacts with extinct mammals has been noted from time to time in America, this occurrence is of exceptional interest by reason of the clear mingling of artifacts with remains of extinct forms in apparently undisturbed original deposits, as also by reason of the wide-spread distribution and the interesting geological and palæontological relations represented.

Studies of a number of problems relating to occurrence of early man in America have been under way in the past year. The attempt is being made to examine as carefully as possible evidence from certain of the outstanding localities with a view to obtaining a clear understanding, first, of the nature of the association of human remains with extinct faunas, second, regarding the geologic and physiographic conditions under which such relations occur

and, third, regarding place of the associated faunas in the time sequence. Assuming the association of artifacts with extinct types of life in formations which antedate the present geological stage by a considerable period, it becomes necessary to determine with exactness the chronology in terms of geology and palæontology.

In connection with the International Geological Congress it was possible for Mr. Merriam to visit the John Day region of eastern Oregon in which continuing investigations conducted by Dr. John P. Buwalda, Dr. Chester Stock and others have carried forward the results of earlier investigations dating back more than thirty years. The results of certain of the most carefully worked-out studies in this region are now approaching the point of publication. In the meantime, other researches upon invertebrate faunas by Dr. E. L. Packard, of the University of Oregon, with modest support from the Carnegie Institution of Washington, have brought to light extremely interesting faunas of the Mesozoic and Palæozoic which are destined to have much importance in the palæontological story of the Pacific Coast region.

Researches conducted in the Grand Canyon region through association with the National Park Service have brought significant results. Important work has been done by Edwin D. McKee, Naturalist of the Grand Canyon, on certain of the later formations of the Grand Canyon section. Dr. N. E. A. Hinds, of the University of California, with several assistants, has made a careful study of formations of the Algonkian, the oldest group showing the rocks practically unchanged. Dr. Ian Campbell and Dr. John H. Maxson, of California Institute of Technology, have made significant studies on Archean rocks, the most ancient in the Canyon section. Among other points of interest, the work of Campbell and Maxson has brought out the fact that there appear to be regions in the Grand Canyon Archean where the texture and structure give evidence that the existing rocks are derived from a sedimentary formation of the sandstone type.

In another direction, the work of Dr. R. W. Chaney, of the University of California, in palæobotanical studies has brought out a wealth of information as to the Tertiary floras of the Pacific Coast region. Dr. Chaney has also made important contribution by his studies ranging from China through the South American region covering comparison of existing floras in their relation to types of fossil floras of various formations on the Pacific Coast.

Researches of Dr. Remington Kellogg on the structure, classification, and history of the whale group have continued the extremely important development of knowledge regarding evolution of this interesting group. The studies by Dr. Kellogg constitute one of the most important contributions to palæontology in recent years, and one of the most significant interpretations of the evolution of any mammalian group.

Researches by J. P. Buwalda

Intermittently during the spring, summer and fall of 1932 field investigations were advanced in two areas: the Tejon Pass district and in northern Owens Valley.

In the Tejon Pass Region the areal geology is being mapped and the faulting is being intensively studied with a view to ascertaining the nature of the movements on the San Andreas fault and its branch faults, involving several mountain blocks. It is hoped that the relation of the deformation in the Coast Ranges to that of the Sierra Nevada can be determined by these studies.

In Northern Owens Valley the steep and normal faults, along which the Sierra Nevada has been uplifted and between which Owens Valley was formed by relative depression, are being mapped in detail and their age relations to alluvial formations of approximately known age are being found in as many cases as possible. The last chapters in the Tertiary and Quaternary history of this interesting region are becoming known in terms of tectonic movements, erosion, deposition and concurrent and subsequent further deformation.

*Researches on Algonkian Formations of Grand Canyon National Park,
by Norman E. A. Hinds*

This study of Algonkian formations was started during a brief visit to the Grand Canyon in 1931, made at the invitation of Dr. J. C. Merriam to outline a program of pre-Cambrian research in connection with the development of the general educational program in that National Park. In 1933, the writer, accompanied by C. E. Van Gundy, Georges Vorbe and E. C. Doell, graduate students in geology at the University of California, spent May, June and July in mapping certain of the Algonkian areas and in detailed examination of the field relations of the various formations. Algonkian rocks are exposed in at least eight localities between the north end of the Grand Canyon and the mouth of Tapeats Creek, 80 miles to the west:

1. The largest area lies in the eastern part of the Canyon to the west and north of the great bend of the Colorado River. In this area alone are found the later Algonkian Chuar strata which extended from the north side of Nankoweap Valley on the west side of the Colorado into an unnamed valley to the south of Chuar Creek, a distance of about 12 miles. On the east side of the Colorado, limited exposures of the Chuar are found for some distance to the south of the mouth of the Little Colorado. The earlier Unkar beds extend from their contact with the Chuar westward nearly to Newberry Butte on the north side of the river. On the east and south sides of the Colorado, Unkar beds are found from about 3 miles south of the mouth of the Little Colorado River to Mineral Canyon 10 miles to the west. The area on the west side of the Colorado was studied by the late Dr. C. D. Walcott in 1880, and the names of the two principal groups, Unkar and Chuar, were taken from tributaries to the Colorado in this section. In 1933, Chuar exposures in the Nankoweap and Kwagunt valleys at the north end of the Grand Canyon and those of the Unkar on the south side of the Colorado from its northern margin to the canyon of Seventy-five mile Creek were mapped.

- 2, 3. Small areas of Unkar strata are present in the canyon of Vishnu Creek and in the next canyon to the west.

4. A considerable thickness of the Unkar occurs at the head of the inner gorge of Clear Creek on the north side of the Colorado about 5 miles to the west of the first area. More than half of this was mapped during the 1933 season.

5. Extensive exposures of all members of the Unkar are found near the mouth of Bright Angel Creek on both sides of the Colorado River and also in Bright Angel Canyon as far as Manzanita Point. The mapping of this was completed in 1933.

6. A small area is located in Hindu Amphitheatre about 3 miles above the mouth of Crystal Creek.

7. In and near Shinumo Canyon is the type section of the Unkar mapped and studied by L. F. Noble.¹

8. In the Lower Granite Gorge near the mouth of Tapeats Creek, Unkar strata extend for about 3 miles along the Colorado River.

Besides mapping the areas previously noted, a partial section of the Chuar division was measured in Nankoweap and Kwagunt Valleys and partial or complete sections of the Unkar in the eastern area on the south side of the Colorado and in the Bright Angel district. Detailed studies were made of the Archean surface upon which the Algonkian sediments were deposited; of the various formational units of the Algonkian and their relations; of conditions of the sedimentation; of structure, especially the exceedingly complex faulting; of topographic evolution which followed the accumulation of the Algonkian deposits; of the earliest Cambrian (Tapeats) deposition of the region; and of the intrusive and extrusive igneous rocks. Large collections were made in all of the areas and these are now being examined in the laboratory.

A few preliminary statements concerning other results of our field season are given below, but completion of the field work and extended laboratory study is needed before opinions and conclusions can be satisfactorily advanced.

The lower Unkar strata lie upon a monotonously even surface which had been etched into steeply upturned Archean schists and associated igneous rocks; the relief of this surface in no place examined by us exceeds 20 feet. Denudation, long continued above sea-level, probably was finished by ocean waves as the low-lying Archean land sank below sea-level, though of course the possibility of a peneplain developed by lateral corrasion by streams also must be entertained. The extent to which Archean relief had been destroyed is unknown, as exposures of the ep-Archean surface are limited to short cross-sections in the canyon walls. It is worthy of note, however, that in southern Arizona, where the Apache group lies on Archean schists and granite, the ep-Archean surface shows similar monotony of relief.

Sedimentation during Unkar time seems to have been continuous, since no important discordances have been observed between the principal members of the terrane; local erosional unconformities are met at various horizons but these can not be traced for any great distance. The Unkar is dominantly a "red bed" series, though the proportion of iron present

¹ L. F. Noble, *The Shinumo Quadrangle, Grand Canyon District, Arizona*, U. S. Geol. Surv., Bull. 549, 37-60, 1914.

in the sediments ranges widely in the various formations and in various members of each formation. A considerable thickness of sandstone and shale tentatively assigned to the Dox is green or white in color. Except for the limestones of the Bass, the sediments are chiefly clastics, but the lithologic types are numerous. Until laboratory and field studies are carried further, it seems inadvisable to discuss the nature of the sediments or the conditions of sedimentation.

In Unkar time, sills of diabase were intruded into the sediments at various horizons and basaltic lavas were extensively erupted. A 300-foot sill in Bright Angel Canyon shows differentiation of a red syenitic rock and abundant micropegmatite from the basic magma. The sedimentary rocks, especially the shales both above and below this sill have been metamorphosed to various degrees. Thick series of flows are exposed in the upper part of the Dox near the great bend of the Colorado River, but do not appear in any of the other areas. The suggestion is that this activity occurred near the close of Unkar time, and that, if flows were elsewhere erupted, they have been eroded away.

The Chuar terrane is known only from Walcott's description. Our findings show that it is composed chiefly of shales, sandy shales, muddy limestones and minor amounts of sandstone, most of which is rather fine textured. All of the lithologic types range in color through various shades of gray-yellow, red, brown and green, though, except in the sandstones, gray-yellow and green predominate. The contrast in color of Unkar and Chuar sediments is striking. A partial section of the Unkar, measured in Nankoweap Valley at the north end of the Canyon, shows three principal divisions:

Upper

Yellow and black crumbly shales with interstratified limestones of various types, minor amounts of sandy shale, and a single flow of deeply weathered vesicular lava, probably basalt 1464 feet

Middle

Rather well indurated, medium-grained, cross-bedded red sandstone with minor amounts of red sandy shale below, between and above the two principal sandstone ledges 137

Lower

Crumbly shales above and gray and tan muddy limestones, shales of various colors, and minor beds of fine-grained sandstone below.

The base of the Unkar is not exposed in this locality..... 478

The fault-block mountains previously described were deeply eroded and the weak Chuar and upper Unkar beds were stripped away from all exposed sections, except that in the eastern part of the Grand Canyon. Before Cambrian deposition began, the mountains had been reduced to low hills and ridges whose relief varied with the nature of the rock exposed at the surface. Where erosion had exposed the Shinumo quartzite, prominent ridges characterized by steep slopes and great talus piles at their bases

were developed but, where less resistant members were being attacked, the relief was distinctly low and subdued.

Careful search was made for fossils or other evidences of life, but, outside of many markings on rock surfaces which possibly may be organic and the already recognized calcareous algæ, nothing was discovered. Algal limestones are abundant in the Bass member or the Unkar and also in the Chuar. In the Chuar at various horizons are considerable thicknesses of carbonaceous shales.

Researches by Remington Kellogg

In furtherance of the project for "A study of the evolutionary history of the cetaceans," California and Oregon were visited during September and October 1932. At the invitation of Dr. Wm. A. Bryan, director, Museum of History, Science and Art, Los Angeles, a report dealing with the skull and skeleton of a cetothere from the Modelo formation was prepared. Following the completion of this report, five days were spent with Lawrence W. Bolles as assistant investigating the occurrence of cetacean remains in a bed of arkose located at an elevation of approximately 3800 feet on a short spur near Cajon Pass, San Bernardino County, California. Sufficient remains of an extinct porpoise were found to show that this formation belongs to the Lower Miocene as now understood in Pacific Coast chronology. In company with Eustace L. Furlong, the Pico formation in the vicinity of Humphreys, California, was re-examined. The discovery here of an incomplete mandible of a large mysticete tends to confirm the Pliocene age of this deposit. At Santa Barbara, the private collection of Dr. A. P. Ousdal was examined. Dr. Ousdal generously donated a skull of a small cetothere which he had collected in the bituminous dolomite near Santa Barbara. This specimen, in conjunction with those previously known from this formation, will permit more accurate comparisons with other marine faunas from the Miocene of California. The recently acquired material in the Museum of Paleontology, University of California, was examined and additional occurrences of previously described forms, particularly *Desmostylus*, was noted.

Two weeks were devoted to the study of a cetothere belonging to the Condon Museum, University of Oregon, Eugene. This cetothere was collected near Newport in the Astoria formation. Dr. Earl L. Packard collaborated in the preparation of a report on the occurrence and description of this specimen.

At Chicago, Dr. O. C. Farrington and Dr. E. S. Riggs of the Field Museum of Natural History, made the necessary arrangements for the preparation of a report on the skull and mandibles of a cetothere collected in the Patagonian marine formation near the Bay of Solano, Patagonia, Argentine Republic.

The able assistance of the artist, Sydney Prentice, in the preparation of illustrations for these reports is likewise acknowledged.

During May 1933, previously described archæocete material belonging to the Museum of Comparative Zoology, Cambridge, the American Museum of Natural History, New York, and the Academy of Natural Sciences of Phila-

delphia, was re-examined in connection with the report on this group now in the course of preparation. At the Peabody Museum, Yale University, New Haven, Leslie E. Wilson generously permitted the examination of a collection of fossil cetaceans which he had made in Miocene deposits near Woody, Kern County, California.

The following papers were submitted for inclusion in Publication No. 447 of Carnegie Institution of Washington:

Earl L. Packard and Remington Kellogg: A new cetothere from the Miocene Astoria formation of Newport, Oregon.

Remington Kellogg: A new cetothere from the Modelo formation at Los Angeles.

Remington Kellogg: The Patagonian fossil whalebone whale, *Cetotherium moreni* Lydekker.

Publications issued during the year are listed in the Bibliography of this Year Book.

Researches by Chester Stock

Three research projects have been carried forward, as follows:

(1) In association with John C. Merriam and John P. Buwalda, a comprehensive survey is being made of available information relating to the Tertiary history of the Great Basin of western North America. This work involves the completion of studies initiated and developed some years ago by Mr. Merriam in an attempt to synthesize our knowledge concerning western Tertiary horizons and faunas and the correlation of individual segments of Tertiary history. To this end the Correlation Paper, as the accumulated manuscript has come to be called, attempts to survey the field from the time of the early studies of Leidy, Cope and Marsh to the present, giving a critical analysis of the geologic and palæontologic bases for age determinations and correlations of particular horizons. In this connection, an attempt is being made to reach an understanding of the state of our knowledge concerning the constitution and sequence of vertebrate faunas now recorded from this region, involving a critical revision of all known faunas. A comprehensive bibliography is also being prepared.

(2) With completion of the memoir on the *Felidæ of Rancho La Brea*, issued as publication No. 422 by the Carnegie Institution, study of another group of mammals, namely the Camelidæ, occurring in the Pleistocene fauna of Rancho La Brea, is now in progress. Abundant and well-preserved remains of the extinct camel, *Camelops hesternus*, permit adequate comparisons with the living camels of the Old World and with the llamas of South America. The important relationships of the Pleistocene form to modern types are being established by these comparisons. Further comparative studies are planned to determine the relation of *Camelops* to antecedent forms of the North American Tertiary.

(3) In co-operation with the Academy of Natural Sciences of Philadelphia, the University of Pennsylvania Museum and the California Institute of Technology, the occurrences of an early flint culture and remains of extinct mammals, including mammoth, bison, horse and camel, in Quaternary deposits located south of Clovis, New Mexico, were investigated during the

spring and summer. Associated in the field work with Mr. Edgar B. Howard, representing the Academy of Sciences and the University of Pennsylvania Museum, were C. Stock, F. D. Bode, R. W. Wilson and H. D. Curry of the California Institute. Field investigations of the palæontological aspects of the problem of early man in this region of New Mexico included a careful topographic and stratigraphic survey of several critical areas with particular view to establishing accurately the position of the mammalian remains with reference to the archæological materials. This was accomplished satisfactorily. In addition, collections were made to permit a comparison and identification of the several types of mammals that are represented. Study of the collection is now in progress. A discussion of the field occurrence and of the fauna will be published later.

Several papers which during the past year have been in process of completion, have now been published in Contributions to Palæontology, Publication No. 440 of the Carnegie Institution.

It is fitting to record at this time that Mr. J. D. Laudermilk of Claremont, California, has undertaken the microscopic examination of some of the fossil or subfossil organic remains occurring in the important Gypsum Cave deposit of southern Nevada. Chemical analyses have also been made of this material by Mr. Laudermilk. Although the studies are still in progress, noteworthy results have been obtained. Thus the presence of thoroughly desiccated remains of hide among the organic remains has been definitely demonstrated. It appears quite probable that the specimens so determined belonged to the extinct ground sloth *Nothrotherium*. Furthermore, the dung of this mammal has been carefully examined with a view to determining the composition of the plant assemblage represented in this material. The results are of considerable significance in shedding light on the food habits of *Nothrotherium* and in furnishing information concerning the flora which existed in the vicinity of Gypsum Cave during the period when the region was occupied by ground sloths. Significant inferences as to the climatic conditions of that time might reasonably be expected from these data.

Mr. Laudermilk has kindly furnished the following preliminary list of plants present in the dung material:

<i>Yucca brevifolia</i>	Grass (species not identified)
<i>Yucca baccata</i>	Juniper
<i>Ephedra irridis</i>	<i>Sphæralcea</i>
<i>Atroplex hymenelytra</i>	<i>Agave utahensis</i>

An unidentified leguminous plant, a willow, and the species *Yucca mohavensis*, also may be represented, but the identification of *Larria* is doubtful.

An account of these studies will be published by Mr. Laudermilk.

PHYSICS

REPORT OF COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS

This special Committee was appointed in December 1932 by President Merriam to consider coordination of possible continued support by the Institution of research on cosmic rays. Various conferences of the Committee and consultations with Messrs. A. H. Compton and R. A. Millikan, Research Associates of the Institution, and other interested investigators who had submitted proposals for research in this field were held. The first report of the Committee was submitted in January 1933 with various memoranda regarding possible procedure and estimates of funds required for the year 1933.

The Committee felt strongly that what may be called the geographical reconnaissance in cosmic-ray research has yielded profitable results but that the principal need at present is more precise and continuous series of records at a selected number of stations (6 or 8). It seems desirable that such stations be well distributed both as regards latitude and longitude in order that the data obtained continuously and simultaneously at the various points for rather long periods may be subjected to the most careful analysis from the statistical viewpoint. Thus the observations so far reported indicate features of the phenomena which, while infrequent and while differing materially from the majority of data obtained during short series, represent something definitely real. A correct interpretation of such features may not be expected from short series of observations at different seasons in different localities. Another feature is that of diurnal variation or change from day to night, regarding which available data are not conclusive, and which it appears can be thoroughly studied only through continuous photographic registration at several stations in high altitudes over long periods, supported by shorter series of continuous records at different altitudes in the neighborhood of the selected stations. In addition to continuous records at different altitudes at such fixed stations, it appears desirable to augment data in the higher atmosphere, such as have been obtained by Regener in pilot-balloons, by Millikan in airplanes, and by Kolhörster in manned balloons, although it is manifestly impossible to obtain continuous records for any great length of time at fixed altitudes by such means.

The instruments used in many of the investigations up to the present time have had to be readily portable and subject to limitations of size, weight, and construction. At fixed stations more sensitive instruments could be used and the present large probable errors of the observations could be reduced greatly. This might lead to the discovery of many important facts and relationships at present masked by the size of the observational errors. Hence the Committee agreed that a chief feature in organizing research, as suggested above, should be the coordination of instrumental and recording devices. Each design at present being used by the various investigators has certain points of superiority. Therefore, cooperation was

suggested looking toward production of a design suitable for precise recording at fixed stations with methods for systematic absolute control. The Committee, as a result of its conferences, found that all those concerned were ready and eager to contribute suggestion and constructive criticism for the preparation of a suitable design.

Consideration of applications for support of the proposed cosmic-ray research again emphasized not only the desire of all concerned to cooperate but also the need through coordination of effort to make the most effective use of such funds as might be available. While it is recognized that a certain amount of scientific competition is desirable and must be encouraged, the deliberations certainly brought out clearly the need of definite collaboration and cooperation to clarify not only the problems but also the interpretation of results.

The importance to geophysics of developing the cosmic-ray investigations can not be overestimated. Thus the question whether the rays are initially corpuscles or protons is one of far-reaching value in the study of the Earth's electric field and its variations, bearing particularly on such questions as the maintenance of the Earth's negative charge, an explanation of the 24-hour universal wave in the diurnal variation of potential gradient, the relation to thunder-storm centers, and correlation with magnetic disturbances. In the selection of cosmic-ray recording stations, therefore, cooperation, so far as is possible, is indicated at or near existing magnetic observatories where continuous geophysical registrations are made—for example, in atmospheric electricity, earth-currents, terrestrial magnetism, and meteorology, with concomitant observations of correlated phenomena, such as fluctuations of the ionized regions of the upper atmosphere, solar activity, etc. Among stations suggested as approaching this requirement are: The Cape Town Magnetic Observatory of the University of Cape Town, South Africa; Auckland or Wellington, New Zealand, or the Christchurch Magnetic Observatory of the Department of Scientific and Industrial Research of New Zealand; the Huancayo Magnetic Observatory of the Carnegie Institution of Washington (at an elevation of 11,000 feet with altitude nearby as great as 19,000 feet readily reached); the Honolulu Magnetic Observatory of the United States Coast and Geodetic Survey in Hawaii (Mauna Loa, 13,675 feet); the Dehra Dun Magnetic Observatory of the Survey of India (within striking distance of great altitudes in the Himalayan Mountains). While there is no magnetic observatory within the United States which is situated at considerable elevation, the establishment of a station in the neighborhood of Pasadena was recommended because of proximity to the Mount Wilson Observatory of the Institution and to the California Institute of Technology. This point is also between the Tucson Magnetic Observatory in Arizona and the Sitka Magnetic Observatory in Alaska of the United States Coast and Geodetic Survey. A station in the neighborhood of Boston would also be desirable.

The Committee agreed that the investigation of cosmic-ray problems from the laboratory point of view must be left for the present to universities and organizations having such research under way—for example, among others, the California Institute of Technology, the Bartol Research Founda-

tion, and Harvard University—and through correlation with high-voltage research also in progress—for example, at the California Institute of Technology, Massachusetts Institute of Technology, and Carnegie Institution of Washington.

The above recommendations are already being realized through a grant by the Carnegie Corporation of New York to the Institution. This grant is being administered upon recommendations of the Cosmic-Ray Committee, in direct cooperation with the program of the Department of Terrestrial Magnetism of the Institution. Already a design of recording instrument has been prepared by A. H. Compton and R. H. Bennett in which are embodied certain constructive suggestions of R. A. Millikan and H. V. Neher—the result of their long experience in cosmic-ray technique and investigation—and of colleagues abroad, including among others Dr. E. Steinke of Königsberg and Dr. B. F. J. Schonland of Cape Town. A brief account of the instrument proposed is given in the report submitted by A. H. Compton, research associate, which follows.

The completion of certain portions of the world-wide cosmic-ray survey has been accomplished by the work of J. M. Benade en route from India and that of P. G. Ledig in connection with magnetic field-work in South America. Advantage has been taken of the opportunity presented by the forthcoming second Byrd Antarctic Expedition to provide funds so that the scientific personnel headed by T. C. Poulter may obtain cosmic-ray data at the two proposed base-stations in Antarctica—Little America and a base about 200 miles from the geographic South Pole. Reference in more detail is made to this matter in the following report by Dr. A. H. Compton.

A grant to provide for observations to determine the angular distribution of the cosmic radiation was made by the Committee to supplement provision made by the Bartol Research Foundation of the Franklin Institute. Dr. Thomas H. Johnson of that Institute, as a Research Associate of the Institution, summarizes his results in Mexico and Panama on this subject in the following report. Similar observations in Mexico by Luis Alvarez of Dr. Compton's staff made at the same time as Dr. Johnson's observations confirm the latter's results and are reported upon briefly in Dr. Compton's attached statement, as are also the results of Professor J. C. Stearns in Colorado.

Plans were made to have Dr. J. C. Street and H. R. Mimno of the Jefferson Physical Laboratory of Harvard University spend two months beginning July 3, 1933, at the Institution's Huancayo Magnetic Observatory and elsewhere in Peru securing observations relating to special researches pertaining to penetrating-radiation. Preliminary arrangements were also made for T. H. Johnson of the Bartol Research Foundation to spend one or two months at the Observatory, beginning early in August 1933, to carry out observations at the Observatory and in the general region of the Observatory with Geiger-Müller counter equipment in the test of theories relating to penetrating-radiation.

Continuous photographic records of the penetrating-radiation were made by Dr. J. E. I. Cairns at the Huancayo Magnetic Observatory. These

records, extending over a period of several months, indicated the potential-difference across a fixed high resistance through which the ionization-current was flowing. Information was obtained on the diurnal variation, frequency and magnitude of "bursts," and concerning the effects of thunder-storms. Preparations were being made at the end of June 1933 for further studies of the penetrating-radiation both at the Observatory and in the field. Apparatus was under construction at the Observatory for use in the high country northeast of Huancayo, and additional equipment was en route June 30, 1933, from Washington.

The statistical aspects of the cosmic-ray data have also received consideration from Messrs. M. A. Tuve and A. G. McNish of the Institution's staff. This has applied particularly to angular distribution of the cosmic radiation.

In particular, the Committee and the Research Associates of the Institution appointed upon its recommendation have established contact with our foreign colleagues in this field of investigation. It is felt that the cordial response in this connection will do much to develop world-wide coordination of the general contact, both in observatory operation and in those laboratory researches so necessary for interpretation of the results obtained.

W. S. ADAMS
JNO. A. FLEMING
FRED E. WRIGHT

Compton, A. H., University of Chicago, Chicago, Illinois. *Studies of cosmic rays.* (For previous report see Year Book No. 31.)

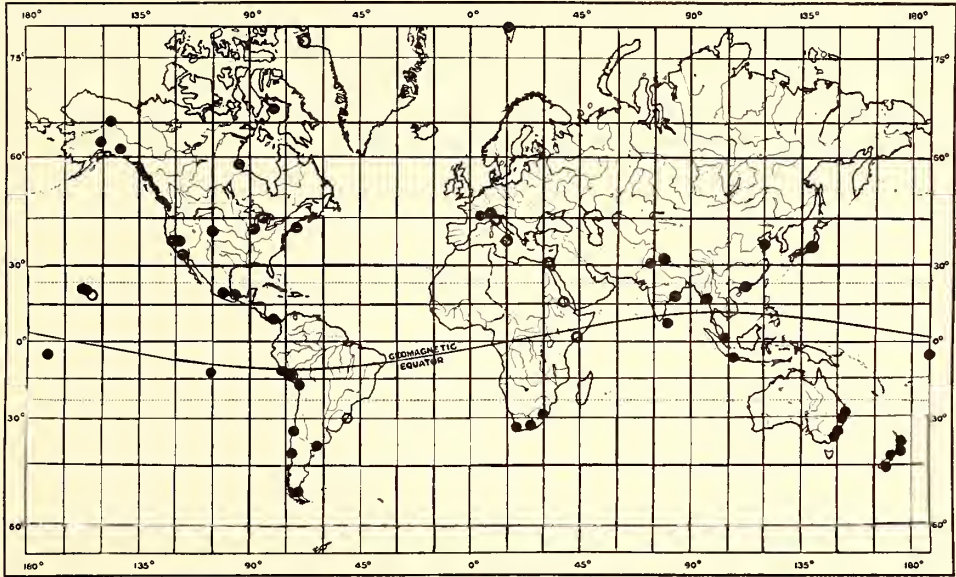
The activities that have been carried on during the past year under my supervision as Research Associate of the Carnegie Institution of Washington, with funds provided by the Carnegie Corporation of New York, have centered about the following four main projects: (1) Continuation of the world survey of the intensity of cosmic rays, which was begun with the help of a grant from the Carnegie Institution in 1931. (2) Measurements of the relative intensity of the cosmic rays coming from different directions at various latitudes and altitudes. (3) Measurements of cosmic rays in the stratosphere, using a Piccard balloon. (4) The design and construction of a number of precision recording cosmic-ray meters, suitable for making continuous records at widely distributed stations.

COSMIC-RAY SURVEY

Our world-wide survey of the intensity of cosmic rays was originally undertaken to find out whether there are any appreciable differences in the intensity of the rays as received in various parts of the earth, and if so to determine the nature of the differences. Though the existence of such differences was not generally recognized, some experiments by Clay seemed to show true intensity changes between Java and Holland. Moreover, theoretical considerations suggested possible variations of intensity with the magnetic latitude, the geographic latitude, the atmospheric potential gradient, oceanic as compared with continental areas, etc. It was hoped that more precise and extensive measurements of the geographic distribution

of the cosmic rays would aid in solving the puzzling problem as to their nature. This hope has been realized in greater measure than could have been anticipated.

With the cooperation of about seventy physicists, representing at least twelve countries, data have now been received from 100 stations in widely separated localities. Measurements have also been made or are definitely planned in not less than 13 additional stations. The wide geographic distribution of these experiments is indicated by the points shown on the accompanying map. The solid circles represent places from which data have been



received, whereas the open circles show locations where measurements are being undertaken but the data are not yet at hand. At many of these places measurements have been made at different altitudes, ranging from sea-level to 20,000 feet. It is planned that two stations (Little America and a point about 200 miles from the geographic south pole) will be occupied by the Second Byrd Antarctic Expedition of 1934-35.

The men in charge of our several associated expeditions and regions in which they worked are:

J. C. Stearns of the University of Denver, Colorado.

A. H. Compton, Switzerland, Hawaii, New Zealand, Australia, Panama, Peru, Mexico, Northern Canada, Michigan.

R. D. Bennett, Massachusetts Institute of Technology, Alaska, California, Colorado, Boston.

E. O. Wollan, University of Chicago, Chicago, Spitzbergen and Switzerland.

Allen Carpe, of New York City, at Mount McKinley.

S. M. Naude, University of Cape Town, South Africa.

J. M. Benade, Forman Christian College, Lahore, India, Malaya, Java, China, Japan, Hawaii.

P. G. Ledig, Carnegie Institution of Washington, Southern South America.

In addition, work is now under way by expeditions directed by the following men:

D. la Cour, Danish Meteorological Survey, Greenland, Denmark.

B. Rossi, University of Padova, Italy, Suez, East Africa.

T. C. Poulter, Byrd Antarctic Expedition, Panama, Magellanes, Antarctic, New Zealand.

The major findings of the expeditions to date are:

(1) The cosmic rays are in general less intense near the equator than in temperate or polar zones. This observation completely confirms the conclusions of Clay. Our measurements indicate that the intensity in polar regions is about 15 per cent greater than near the equator, most of the change occurring between geomagnetic latitudes 20° and 45° . Our finding that there are no measurable differences north of geomagnetic latitude 45° confirms the earlier measurements of Millikan and others.

(2) At high altitudes, the variation with latitude is greater than at sea-level and extends also to higher latitudes. Thus at an altitude of 4360 meters (barometer 45 cm.) our measurements indicate that the intensity at 49° geomagnetic latitude is 33 per cent greater than at the equator, and at 67° it is about 65 per cent greater.

(3) The intensity can be plotted as a function of the geomagnetic latitude (calculated with reference to the earth's mean magnetic poles), but does not follow so closely the geographic latitude nor the magnetic latitude (referred to the local magnetic dip). No systematic differences are found between continental and oceanic areas. These results could not have been established without a survey on a scale comparable with that here undertaken.

It would appear that the only possible interpretation of the dependence of the cosmic rays on the earth's mean magnetic field is that a considerable portion of these rays consists of electrically charged particles which approach the earth from great distances. That they are electrically charged follows from the fact that they are affected by the magnetic field. That they come from distances, large compared with the thickness of the atmosphere, follows from the fact that it is the earth's average magnetic field rather than the local field which determines their intensity. Recent theoretical discussions by Lemaitre and Vallarta and by Fermi have indicated that it is possible by this interpretation to account completely for the observed variation of intensity with magnetic latitude.

In order to fit the observed intensities with the calculated values, it is necessary, however, to assume the existence of a large component of the cosmic rays which is not appreciably affected by the earth's magnetic field. This component represents about 85 per cent of the rays at sea-level and 60 per cent of the rays at 4360 meters (in polar zones), and is therefore the chief part of the cosmic rays as ordinarily measured, though probably not the major part out in space. These rays, unaffected by the earth's magnetic field, would seem to be either photons or some other electrically neutral particle whose nature remains to be determined.

A corollary of the fact that the intensity of the cosmic rays is a function only of the distance from the geomagnetic equator is that in remote space the rays must be isotropic. Of especial importance in this connection is our

observation that within experimental error the intensities at corresponding north and south geomagnetic latitudes are equal. It is upon the assumption of such an isotropic character of the rays that the argument is based which assigns the origin of the rays to regions beyond the confines of our galaxy.

As a result of this survey, a component of the cosmic rays has been discovered whose intensity depends upon the geomagnetic latitude, and which must consist of electrically charged particles entering the earth's atmosphere from remote space. The existence of another component which is independent of the position in the earth's magnetic field has also been confirmed. Our data indicate further that both components are isotropic in space remote from the earth, and support the view that the rays come from very great distances.

DIRECTIONAL EXPERIMENTS

Our directional experiments have been performed, using double coincidence counters of the Geiger-Müller type, and have had two objectives. The first experiment, by J. C. Stearns and W. Overbeck of the University of Denver and R. D. Bennett of Massachusetts Institute of Technology, was designed to determine whether any cosmic ray particles are coming direct from the sun. None were observed. The second group of experiments have had as their object to determine whether the cosmic rays come equally from all azimuths, and if not, how they are distributed.

It can be shown that positively charged cosmic-ray particles entering the earth's magnetic field should be deflected so as to come more abundantly from the west than from the east. Negatively charged particles should come more strongly from the east. If particles of both signs occur, the rays coming from north and south should be stronger than those from east and west. These effects should, however, be appreciable only at those latitudes at which the earth's magnetic field affects the total intensity of the rays, *i.e.* less than 50° from the geomagnetic equator.

At Denver the effect, if any, should theoretically be very small. Stearns and his students, in a paper soon to be published, find no significant difference with azimuth. This result is in reasonably good accord with that of T. H. Johnson and his collaborators, who report a small excess toward the west, almost within experimental error, at both Philadelphia and Mount Washington.

In Mexico the theory predicts that an effect of some kind should definitely be anticipated. Accordingly, Mr. Luis Alvarez carried on a similar set of experiments in Mexico City, and found a marked preponderance in the rays coming from the west as compared with the east. The difference at 30° from the zenith amounted to about 10 per cent. This result was confirmed by measurements made independently at the same time by T. H. Johnson. The direction of the preponderance indicated that the rays which are affected by the earth's magnetic field are *positively* charged, and the magnitude of the difference was about that to be expected if all of the rays which the world survey had shown to depend upon the geomagnetic latitude were included in this positively charged component.

These experiments have therefore supplemented the results of the world survey of cosmic rays in showing that the electrically charged component

of the rays, which that survey brought to light, consists chiefly of positively charged particles. More detailed information on this point is coming from the measurements of T. H. Johnson, now working in Peru with similar equipment, who is presumably describing his experiments in a separate report.

HIGH-ALTITUDES EXPERIMENTS

Professor Millikan, Dr. Stephenson, Mr. Alvarez and Mr. Hsiung have been cooperating with me in preparing to carry on cosmic-ray experiments in the gondola of the Piccard balloon, which it is now expected will fly from Akron about November 15, 1933.¹ Four different cosmic-ray experiments are planned. Professor Millikan is supplying one of the precision electroscopes developed by Dr. Neher and himself to record the ionization in an unshielded ionization chamber. Any data thus obtained will be similar in character to those got by Kolhörster, Millikan, Regener, and others using sounding-balloons, but should be of considerably higher precision up to the altitude attained, because of the larger apparatus and longer time of observation.

Dr. Stephenson has installed one of the cosmic-ray meters used on our world survey, equipped with a recording camera, and surrounded with a shield consisting of a 7.5-cm. layer of lead shot, which is about the equivalent of the shield used in our survey experiments. Such an instrument will measure the cosmic rays in approximate equilibrium with the secondaries from lead, which will afford an interesting comparison with the ionization in Millikan's electroscope, in which the secondary rays will be chiefly from the atmosphere.

Mr. Alvarez has set up a double coincidence counter, similar in type to that which he used in Mexico, to study the direction from which the cosmic rays come. There is reason to anticipate an azimuthal variation at high altitudes, even though none is observed at sea-level. Such variation would mean the existence of electrically charged rays of energy too low to penetrate the earth's atmosphere, and the sign of the charge would be evident from the nature of the variation.

Mr. Hsiung's experiment is a triple coincidence analogue of Bothe and Geiger's famous double coincidence experiment which they thought had established the charged particle nature of the cosmic rays. We wish to determine whether the results of this experiment are the same at high altitudes where the less penetrating components of the cosmic rays predominate.

In planning these experiments we have had the benefit of advice from Professor Auguste Piccard, and the Century of Progress Exposition is co-operating in making the balloon available for the experiments. It is now arranged that Commander Settle, who is to be the pilot, will act also as observer. He has spent considerable time in acquainting himself with the instruments.

NEW COSMIC-RAY METER

The discovery of a component of the cosmic rays whose intensity depends upon the position in the earth's magnetic field, and which is electrically charged, suggests the probability that variations in the earth's magnetic field and in the atmospheric potential gradient may likewise influence their

¹ The flight was realized November 20-21, 1933.

intensity. Many experimenters have from time to time reported systematic variations in the strength of the cosmic rays whose origin has been unexplained. If these variations are real, they are certainly small and are difficult to distinguish from the statistical fluctuations which are inherent in the nature of the rays. It is important to know whether these variations represent real changes in the strength of the cosmic rays and, if so, whether the changes are to be ascribed to variations in terrestrial conditions or to some lack of uniformity in the distribution of the cosmic rays in space. In order to attempt an answer to these questions, the Carnegie Institution has undertaken to make systematic records of the strength of the cosmic rays in a number of widely distributed stations over a period of years. We have been requested to design and construct the recording cosmic-ray meters required for the purpose.

The design of a suitable instrument, developed chiefly by Professor R. D. Bennett and the writer, has been submitted to a number of men familiar with the problem both in this country and in Germany, and one instrument is under construction for purpose of test. According to the present design, the ionization chamber has the relatively large volume of 21 liters and is to be filled with argon under 50 atmospheres pressure. The cosmic-ray ionization will be balanced against that due to the beta rays from metallic uranium, which will give a constant standard of comparison. The current is to be measured by means of a Lindemann electrometer of standard construction, whose reading will be recorded on a continuously moving film. A shield consisting of about 2500 pounds of lead shot will reduce to a negligible value the effect of local gamma-rays. It is estimated that the meter will be several times more sensitive to variations in the strength of the cosmic rays than any similar meter with which we are acquainted. We hope to have the first meter ready for use not later than January 1, 1934, and the others as soon thereafter as the machine work and tests can be completed.

PERSONNEL

During the period from July 1, 1932, to June 30, 1933, the following persons have been employed to assist me in the cosmic-ray researches supported by the Carnegie Institution: Dr. E. O. Wollan, July 1 to Sept. 30; Dr. V. J. Andrew, Nov. 1 to Jan. 31; Mr. Luis Alvarez, Feb. 1 to Mar. 31; Dr. R. J. Stephenson, Apr. 1 to June 30.

During the same period, funds from the Carnegie Institution have been distributed through me to support cosmic-ray researches of the following men, whose work has been described in the above report: Prof. Ralph D. Bennett, Massachusetts Institute of Technology, Cambridge, Massachusetts; Prof. S. M. Naude, University of Cape Town, Rondebosch, South Africa; Prof. J. M. Benade, Forman Christian College, Lahore, India; Prof. J. C. Stearns, University of Denver, Denver, Colorado; Mr. P. G. Ledig, Department of Terrestrial Magnetism, Carnegie Institution of Washington, Huancayo, Peru.

During the report year my associates and I have published several papers representing work supported in whole or in part by the Carnegie Institution. These are listed in the Bibliography of this Year Book.

Johnson, Thomas H., Bartol Research Foundation, Swarthmore, Pa.
Studies of cosmic rays.

By means of a grant made available by the Carnegie Institution of Washington from funds provided by the Carnegie Corporation of New York studies have been made in Mexico and Panama, and will be made in Peru, of the angular distribution of the cosmic radiation. The object of these investigations was (1) to test the corpuscular ray hypothesis which had been invoked by Compton and by Le Maitre and Vallarta as an explanation of the variations in the cosmic-ray intensities with latitude, (2) to determine the relative numbers of such corpuscular rays carrying positive and negative electrical charges, (3) to determine the energy distribution of such corpuscular rays, and (4) to obtain information as to the rate at which these rays lose energy in passing through the atmosphere. The instrument used in these measurements is a sequence of three Geiger-Mueller counter tubes with a circuit for recording the coincident pulses produced by rays which pass through all three tubes. Measurements were made during March and April at three locations in Mexico, namely, Mexico City, San Rafael and Vera Cruz, and with the following results: (1) Previous indications resulting from our measurements on Mount Washington were confirmed, proving the existence of an azimuthal asymmetry in the cosmic radiation such as was predicted by the corpuscular ray hypothesis. This result, in conjunction with the latitude intensity-variations, is substantial proof of the existence of a primary corpuscular radiation entering the earth from sources external to its magnetic field. (2) A more intense radiation was found from the west than from the east, showing that the majority of the corpuscular rays carry positive electrical charges. (3) A study of the distribution of the rays in azimuth showed no indication of the existence of any negative rays, though such would have appeared if they were present with 25 per cent intensity of the positive rays. (4) The magnitude of the asymmetry showed that the rays were more or less continuously distributed throughout the range 3×10^9 to 3×10^{10} volts, and indicated that the asymmetry would persist to equatorial latitudes, contrary to other predictions based on latitude intensity-variations. (5) The angular distribution curves showed that the rays lose energy in the atmosphere at the surprisingly high rate of about 10^9 volts per meter of water equivalent and therefore the discontinuation of further latitude intensity-variations at latitudes above 50° is due to atmospheric absorption and not to the absence of radiation in the energy range immediately below 3×10^9 volts. (6) Measurements made in Panama at the Barro Colorado Island Laboratory of the Institute for Research in Tropical America during the months of June and July have confirmed all of the above conclusions from the Mexico studies and have reduced the number of possible negative rays to less than 15 per cent of the number of positive rays. (7) During the course of these studies the apparatus has been developed for automatic recording and control of the experiments, so that it has become suitable for more extensive observations which would lead to greater precision in the detection of possible negative rays and to a more accurate determination of the energy distribution.

The establishment of the existence of a primary corpuscular radiation with a positive charge and the absence of any negative rays puts stringent limitations on the possibilities as to the origin of the cosmic rays.

Millikan, Robert A., California Institute of Technology, Pasadena, California. *Studies of cosmic rays*. (For previous report see Year Book No. 31.)

The program of cosmic-ray studies which I am directing under a grant of the Carnegie Corporation of New York, administered by the Carnegie Institution of Washington, has been continued as outlined a year ago,¹ with the following results:

GEOGRAPHICAL HIGH- AND LOW-ALTITUDE SURVEY

With the aid of the vibration-free, self-recording instruments developed and built largely by H. Victor Neher, with the assistance of Dr. I. S. Bowen and myself and the shops of the Norman Bridge Laboratory, Dr. Neher and I have obtained very accurate upper-air data up to 22,000 feet in practically all flights made in the five following localities: (1) Cormorant Lake, Manitoba, Canada (latitude 55, magnetic latitude 75); (2) Spokane (latitude 47, magnetic latitude 64); (3) March Field, Riverside, California (latitude 34, magnetic latitude 50); (4) Panama (latitude 8, magnetic latitude 25); (5) Arequipa (latitude 17 S., magnetic latitude 2 N.). Nowhere did these flights yield any difference between day and night—three of the flights having been made at night time—and no latitude-effect whatever was noticed between Cormorant Lake and Spokane, nor between Panama and Peru. These results are of much significance because of the high accuracy obtained at these high altitudes, where the ionization is more than fifteen times as great as at sea-level. At 22,000 feet, however, we found a 40 per cent higher intensity at Cormorant Lake and Spokane than at Panama and Arequipa, and an 11 per cent higher intensity at Spokane than at Riverside.

Very careful observations at sea-level with these same instruments, taken on voyages from Seattle to Mollendo, Peru, South America, showed no latitude-effects whatever above latitude 34, a result completely confirming my own observations of 1930 of lack of latitude-effect between Pasadena (latitude 34) and Churchill, Manitoba (latitude 59). Between Pasadena and Panama, however, we found at sea-level a decrease of 6.8 per cent, but no further decrease down to Mollendo. This confirms the observations made by the observers of the Carnegie Institution of Washington on the *Carnegie* in 1928, who found a difference of between 5 and 7 per cent in their readings in the equatorial zone and the temperate zones. It differs from the observations made between Pasadena and Mollendo by Cameron and myself in 1926, who observed no difference at sea-level between these same latitudes, although we estimated our error at 6 per cent, so that the results of this year's observations are just on the limit of the observational uncertainty as we then estimated it. Our sea-level differences between equatorial and temperate latitudes are smaller than those reported by Clay and by Compton, but we have two self-recording instruments which are now on voyages around the world, the results of which should settle very definitely how great these sea-level differences actually are.

¹ Year Book No. 31, 335, 1932.

COSMIC-RAY INTENSITIES IN THE STRATOSPHERE

With the new but less sensitive type of electroscopes mentioned in our preceding report, Dr. Bowen and I, in cooperation with the Weather Bureau, have sent up recording instruments during the past year to altitudes as high as those reached thus far by any instruments carrying electroscopes, namely, altitudes at which, according to the Weather Bureau's official measurement and report, the barometric pressure had fallen to 16 mm. of mercury. We did not obtain, however, good readings at pressures lower than 60 mm. of mercury. But we did obtain two successful flights which checked well, so that we have established the intensities in these high altitudes more accurately, we hope, than they have been before obtained. The only other observations with which ours can be compared are those of Regener, made during the same summer in Europe, and his data compare in the main favorably with ours. From our new observations, combined with the Millikan-Cameron under-water data and the Bowen-Millikan-Neher airplane data up to altitudes of 29,000 feet, we have been able to find with greater accuracy than heretofore the total energy entering the earth in the form of cosmic rays. This comes out approximately half the total energy coming in from the stars, and we estimate from these measurements and the distribution of nebula in the universe that the total radiant energy in the universe existing in the form of cosmic rays is from thirty to three hundred times that existing in all other forms of radiant energy combined.

DIRECT MEASUREMENTS OF THE ENERGY OF COSMIC RAYS

These measurements have been carried out with increased precision and reliability by Carl D. Anderson and Seth Neddemeyer at the Norman Bridge Laboratory. Our apparatus has measured accurately particle energies up to three billion volts, and one result of outstanding importance is that the positive and negative particles are essentially equal in number and in the distribution of their energies. This is of very great significance for the theory of cosmic rays. By comparison with the foregoing distribution of energy among particles, Dr. Neher and I have been able to estimate energies at high altitudes from the observed absorbing effects in lead screens taken up to 29,000 feet in airplanes, and have thus demonstrated directly that at this higher altitude the rays are very much softer than at sea-level. These experiments are being continued in the hope of obtaining a quantitative estimate as to that softness.

DISCOVERY OF THE POSITIVE ELECTRON

The most far-reaching and fundamental discovery that has come from these studies is the discovery, through the foregoing energy measurements of the existence of the positive electron, of the same mass as the negative electron resulting from the encounter of the incoming cosmic rays with the nuclei of atoms. This discovery was made and published September 1932; the results were extended and published in full in March 1933, and in the same month publication made from the Cavendish Laboratory by Blackett and Occhialini confirmed completely our results at the Norman

Bridge Laboratory. Dr. Anderson's discovery, made and published in April 1933, that these positive electrons are also produced by the gamma rays of thorium "C" is of fundamental importance and, with the corresponding studies in the field of cosmic rays, represents perhaps the most far-reaching advance in our knowledge of the structure of matter which has been made in this century.

AGE OF THE ROCKS

The active study of the local radiation (which must necessarily be an element in all cosmic-ray tests on the earth) and of the uranium and thorium content of rocks has been continued, and new methods have been developed by Dr. Robley D. Evans and Mr. Russell W. Raitt for measuring accurately the thorium as well as the radium content of rocks bearing but very small quantities of radioactive materials. These advances have been responsible for the development of a rather elaborate program aiming at the application of the foregoing results to the determination of the ages of rocks.

GEIGER COUNTER EXPERIMENTS

Geiger Counter experiments directed toward the elucidation of the so-called East-West effect, brought to light by the experiments of Johnson and Alvarez at Mexico City, have been pursued actively by Dr. S. A. Korff, who finds no East-West effect on Mount Wilson (latitude 34) and none at Flagstaff (11,000 feet, latitude 30). These measurements of Dr. Korff are being continued with new appliances in the equatorial belt.

NUCLEAR ABSORPTION OF COSMIC RAYS

New groups of rather elaborate experiments have recently been undertaken by Dr. Bowen, Dr. Neher and myself on the nature of the nuclear absorption of cosmic rays. The law of variation of this absorption with atomic numbers is at present completely unknown, although Schindler has done some excellent work upon it. It is of crucial importance for the testing of existing theories of cosmic rays, in particular Dirac's theory.

COSMIC-RAY SHOWERS AND COSMIC-RAY BURSTS

One of the important discoveries of the past year, which has come directly from the foregoing energy measurements of Dr. Anderson, is that the impact of the primary cosmic rays with a nucleus very frequently, if not generally, gives rise to a positive and negative pair, in some instances to more than two tracks emanating generally, though not always, from a common center, which tracks may be in number, according to our observations, anything between two and twenty. If we call these multiple tracks, of any number from two up to twenty, "showers," such showers are found to represent a very considerable portion of the results of primary encounters with nuclei. The nature of the encounters which give rise to these showers is still unknown, but Dr. Anderson, Mr. Pickering, and Mr. Neddemeyer are making rather elaborate studies upon the phenomenon with the aid of the Wilson cloud-chamber technique and the powerful magnetic fields which we are here producing.

There is another phenomenon known as cosmic-ray "bursts," in which the loss of charge of the recording electroscope may correspond to the release in the electroscope of as many as 25 million pairs of ions. Whether these ions are all released by the energy of the incoming cosmic rays or by energy derived from the battery with which the electroscope is charged is a very fundamental point which is at yet undetermined, though the latter theory seems at present the most satisfactory. Doctors Bowen, Neher, Korff and myself are making extensive observations in the hope of settling the question as to which of these possibilities is the correct one.

Compton, Karl T., Massachusetts Institute of Technology, Cambridge, Massachusetts. *Research in high vacuum spectroscopy*. (For previous reports see Year Books Nos. 28-31.)

During the past year the vicissitudes incident to moving the apparatus from Princeton, a fire and instrumental difficulties, have been overcome and the vacuum spectrograph is now in excellent permanent adjustment and capable of use on a wide variety of problems at short notice. Its unique features are (first) broad range with high dispersion and resolving power and (second) a differential pumping system which permits the maintaining of a good vacuum in the spectrograph while maintaining whatever gas pressure is necessary in the discharge tube for excitation and the type of spectrum under investigation. On Schumann plates 24" in length the spectrum is spread out from 0 to 2400A in excellent focus throughout. The photographic intensities are surprisingly uniform down to 500A, below which they gradually diminish in intensity down to about 200A. For shorter wave-lengths a grazing incidence spectrograph must be used and such an instrument has been built and is in operation.

The spectra of helium neon, argon, krypton and xenon have been photographed systematically over a wide range of excitation conditions and these plates are now in process of measurement and computation. They should permit the completion of the analysis of the higher spark spectra begun in 1929 and also the analysis of several spark spectra of krypton and xenon, none of which have hitherto been analyzed. The present measurements are of high precision, since the longer wave-length region of each spectrum has had superposed on it iron arc standards which overlap with the higher orders of all strong lines in the shorter wave-length regions of the plate.

As a by-product to this investigation, and in collaboration with the Harvard Observatory, it has been shown that the two strongest hitherto unidentified lines in the spectrum of the gaseous nebulae are due to "forbidden transitions" in doubly ionized neon. This pair of lines at 3869 and 3968 has the same wave number difference as occurs between two pairs of lines at 490. The laboratory results on which this investigation was based come from the work with the earlier and smaller vacuum spectrograph at Princeton, but prior to publication it was confirmed by preliminary measurements on the extreme ultra-violet plates of neon taken this spring. It has so been shown that astrophysically neon is a very common element, with an abundance comparable to that of oxygen or nitrogen, whereas on the earth it is a very rare element. This work has been published by J. C.

Boyce, D. H. Menzel and C. H. Payne in the Proceedings of the National Academy of Sciences (vol. 19, p. 581-591, June 1933). Two other investigations in pure astronomy have followed from this discovery, both as yet unpublished. In one, Professor Menzel of Harvard had discovered in B9 stars the normal absorption lines of singly ionized neon, and in the second Menzel and Professor Russell of Princeton are investigating the temperatures that would have been required in the earth's early history for the earth to have lost all of its original helium, most of its neon, and much of its nitrogen. Thus a laboratory investigation in the extreme ultra-violet part of the spectrum has led to the identification in the stars of an element previously known only on the earth.

In addition to this work the spectrograph has been made available to other spectroscopists, notably to Professor George R. Harrison, Director of the M. I. T. Spectroscopy Laboratory, who has been using it for the study of extreme ultra-violet spectra of metals excited in hot sparks, by Professor H. D. Smyth of Princeton University, who used the instrument for three weeks in June, and by several investigators during the summer spectroscopy conference which was held here. Professor Smyth tested his suggestion that emission bands of CO_2 , between 820 and 690A, are associated with the well-known emission bands in the neighborhood of 3000A. The experiments showed rather conclusively that this is not true and are being reported in a note to the Physical Review.

The work here described has been carried on from the beginning with the collaboration of Dr. J. C. Boyce and more recently with the assistance of Dr. Carol A. Rieke, formerly of the Harvard Observatory, who has been engaged to assist in measurement of plates and computations. A portion of the grant has also been used for the partial support of an optical worker for the spectroscopy laboratory, Mr. Harry Hill, who has been engaged in work on the following lines:

- (1) Polishing quartz and glass interferometer flats for the study of hyperfine structure of spectrum lines and for the extremely accurate measurements of wave-lengths.

- (2) The grinding and polishing of quartz lenses of peculiar figure for use with these flats.

- (3) The figuring of glass and speculum mirrors for use in connection with the long focus concave grating set-up in the laboratory.

- (4) The preparation of blanks on which gratings are to be ruled in another laboratory.

The program for the immediate future contemplates completion of the computations and analyses of the spark spectra of the inert gases, after which there is a wide possibility of choice for future activity in connection with either higher order emission spectra or absorption spectra.

Shenstone, A. G., Princeton University, Princeton, New Jersey. *Continuation of research in spectroscopy.* (For previous report see Year Book No. 31.)

The work on line spectra in the Palmer Laboratory during the past year, made possible by grants to the Carnegie Institution of Washington from the Carnegie Corporation of New York, has consisted mainly in an attempt

to complete the analyses of partially analysed spectra. The details are as follows.

THE SPARK SPECTRUM OF RHODIUM

This spectrum is quite complicated and irregular. New wave-length measurements have been made using the 21-foot grating, and a very complete new set of observations of the Zeeman effect has been carried out. The knowledge of the spectrum has been considerably advanced. Dr. J. H. Findlay was employed for this work, partly from university and partly from Carnegie funds.

THE SPARK SPECTRUM OF IRON

Mr. L. C. Green of the department of astronomy has commenced his thesis work under me on the spark spectrum of iron. The experimental work has proceeded far enough to make it obvious that much new wave-length material will be available for the analysis. The source used is the Schuler tube and the spectrum has been photographed on the 21-foot grating.

THE ARC SPECTRUM OF SILVER

The arc spectrum of silver is very incompletely known. It should be similar to that of copper, but the positions of the terms are such as to render excitation difficult. There are many extremely diffuse lines due to auto-ionization. Methods of excitation have already led to the discovery of many new lines and should eventually result in a much more complete knowledge of the spectrum.

THE SPARK SPECTRUM OF COPPER

The thorough analysis of the copper spark spectrum has been my own main concern. New and much more complete observations have extended the spectrum into the extreme photographic infra-red and have made the present analysis about the most complete for any complicated spectrum. The number of lines is about 1500 and they have led to the identification of long series of complicated structures and to several new structures never previously observed. The structures observed comprise the following:

- (a) Even. $3d^{10}$, $3d^94d$, d^95d , d^96d , d^97d
 $3d^94s$, d^95s , d^96s , d^97s , d^98s
 $3d^95g$, d^96g
 $3d^84s^2$
- (b) Odd. $3d^94p$, d^95p , d^96p
 $3d^94f$, d^95f , d^96f
 $3d^84s4p$

The apparatus which has been purchased from the funds granted by the Carnegie Corporation has been in almost constant use during the year. Much of our work could not have been undertaken without that assistance. We are keeping a sum of money in reserve to purchase a new and better grating from Professor R. W. Wood of Johns Hopkins when he is able to supply it. The largest piece of apparatus purchased during the year was a very accurate measuring micrometer made by Adam Hilger of London.

Professor Ladenburg's spectroscopic work has been the continuation of the measurement of the refractive indices of gases and vapors. Mr. F. C.

Dahnken has continued the work in the near ultra-violet, and Dr. C. C. Van Voorhis has assisted in the construction of a fluorite vacuum spectrograph and Jamin interferometer, with which it is hoped to extend the measurements down to the limit of fluorite at about 1250 Å.

BAND SPECTRA

Work on band spectra of polyatomic molecules under the direction of Professor H. D. Smyth has been on two problems.

(A) Mr. T. C. Chow finished his thesis work on the absorption and emission spectra of sulphur dioxide. Concerned primarily with the emission, he has measured a large number of band heads in the region between 2500 and 2000 A.U. with the E-315 Quartz Hilger instrument. A partial vibrational analysis of these and the corresponding absorption spectra will be published in the near future.

(B) Mr. D. N. Read, working on the spectrum of CO_2 , has been studying the excitation conditions of the spectrum with the hope of improving and extending the vibrational analysis. The results are still inconclusive.

FLUORESCENCE

Under the direction of Professor L. A. Turner further studies of the quenching of the fluorescence of iodine have been made.

(A) Mr. J. F. Koehler has studied the quenching of the fluorescence of iodine, excited by the green and the yellow lines of the mercury spectrum, by normal iodine molecules and by added argon. He used the method of photographic photometry with the Steinheil F:3 spectrograph and a photoelectric microphotometer. Making more elaborate corrections for secondary effects than heretofore usual, he showed the validity of an extended Stern and Volmer formula and obtained quantitative values of the various quenching coefficients. This work will soon be submitted for publication.

(B) Professor Turner and Mr. C. O. Siegelin have been investigating the intensity of the anti-Stokes lines in fluorescence, using them as an indication of the number of molecules having more than the minimum of vibrational energy. An F:2 spectrograph with liquid prism of Kipp and Zonen is being used for this work. A photoelectric cell with vacuum tube amplifier is being arranged for direct measurement of intensities.

Committee on Study of Surface Features of the Moon. *Progress report for the period July 1932 to June 1933.* (For previous reports see Year Books 26-31.)

The activities of the Moon Committee in 1932 were affected by the preparations for the solar eclipse expedition of August 31, 1932; during the present year, however, good progress has been made both in the preparation of the photographic map of the moon and in the measurement of the intensity and of the percentage amount of polarization of sunlight reflected by different parts of the moon's surface at different phases of the moon.

The photographic map of the moon, when finished, will consist of a series of photographs taken with the zero corrector lens at the Newtonian focus of the 100-inch reflector and transformed so that in each photograph the moon is viewed along the direction normal to its plane of mean libration. The

method of transformation consists in first projecting the negative (or positive) on a magnesia-coated globe whose diameter (15 inches) is equal to that of the moon's disk, as viewed at the Cassegrain focus of the telescope. This projected image on the globe is similar in its angular relations to that of the surface of the moon and can be photographed from any desired direction. The total length of the optical path (540 feet) in this arrangement is so long that slight differences in temperature along the path influence the quality of the final image. In the construction of the moon house in which the transformations are made, the walls and roof are double with an air space between to allow for outside air circulation and rapid equalization of temperature. The floor of the building is covered with a 6-inch layer of sawdust which serves to insulate the ground thermally and thus to avoid its fluctuations in temperature. The several parts of the transforming apparatus are now of metal instead of wood, which was found to respond unequally to slight changes in temperature and humidity with consequent continuous deformation or shifting of position of the optical system, sufficient to affect the quality of the final image. With the present equipment, the transformation of the selected negatives taken with the 100-inch telescope is progressing satisfactorily and is a routine matter. The preliminary series of photographic maps consists of transformed photographs taken at the Cassegrain focus; the final series will consist of transformed photographs taken with the aid of the zero corrector lens at the Newtonian focus of the 100-inch telescope. These photographs have the advantage that the entire surface of the visible moon is shown at any given phase and is not simply a section of the moon as is the case at the Cassegrain focus. This facilitates the transformation operations and avoids a mosaic appearance on the final sheets of the map. The zero corrector lens is now finished and is used for moon photography whenever seeing conditions are sufficiently good for the purpose.

Measurements of the changes produced in sunlight on reflection at the moon's surface are being continued by several methods. These measurements are made at different phases of the moon and at its different positions in the sky. The changes are of two kinds: (a) changes in relative intensities for different regions of the spectrum; and (b) changes in the amount of polarization for different phases of the moon and for different spectral regions.

For measurements of intensity of reflected light the vacuum thermoelement is used together with ray filters for restricting the range of transmitted wave-lengths. These measurements are direct and the galvanometer deflections can be interpreted in terms of relative intensities. With the aid of a nicol prism mounted in a small telescope tube containing a thermoelement at the focus of the telescope objective, the relative intensities for light vibrating in, and normal to, the plane of incidence on the moon can be ascertained directly. In the ultra-violet and visible ranges of the spectrum, the relative intensities and percentage polarization for different wave-lengths are ascertained by use of a polarization ultra-violet spectrograph between the dispersing prisms of which a Wollaston prism of quartz can be inserted. With this arrangement the spectrum is first photographed without the polarization attachment. The Wollaston prism is then inserted and a

second exposure is made; two additional spectra are thus obtained, which show respectively the relative intensities for light vibrating in and normal to the plane of incidence on the moon. From the difference in intensities of these two spectra for a given wave-length the amount of polarization can be deduced directly. Measurements with the aid of this instrument at the primary focus of the 100-inch telescope are being made by W. S. Adams and are to be made at the Cassegrain focus of the 20-inch reflector, now being erected.

For visual measurements of polarization two methods are used. In the first the polarization photometer eyepiece is employed. Its readings are only moderately accurate because of the lack of sensitivity of the eye to small differences of intensity in the photometric field. The apparatus used in the second method is a modification, by F. E. Wright, of the eyepiece employed by M. Lyot of the Observatory at Meudon. In this method the polarization in the moon beam is exactly compensated by means of a thin plate of glass or celluloid tilted at the proper angle and in the proper azimuth. In the Lyot apparatus the test of exact compensation is made by use of a second tiltable plate so mounted that it can be inclined about an axis either parallel or normal to the axis of tilting of the first lower plate. A Savart plate serves to indicate the presence of polarization in the light. If the polarization of the incoming moon beam is exactly compensated by the first plate, the intensity of the Savart bands remains unchanged as the axis of rotation of the upper tilted plate is shifted from the first to the second position. The unfavorable feature of this arrangement is the fact that the comparison of intensities of the Savart bands in the two positions is made not directly as in a photometric field, but successively and the observer is forced to use his memory in comparing the intensity of the second field with that of the first.

In the improved eyepiece, a direct photometric comparison of the two fields is obtained by the introduction of a bi-quartz plate, each half of which is cut normal to the axis, the one of right-handed quartz, the second of left-handed quartz and cemented in a mount with polished vertical surfaces at the line of junction. The thickness of the plate is such that the rotation of the plane of vibration for the green mercury line, $\lambda 0.5461$, is $+45^\circ$ in the one half and -45° in the second. The axis of tilting of the upper celluloid plate includes an angle of 45° with that of the lower compensating tilting plate. The bi-quartz plate provides a photometric field which enables the observer to determine equality of intensity and exact alinement of the Savart bands and thus to ascertain the angle of tilt of the compensator for which exact compensation is obtained. In the improved eyepiece a Wollaston prism of the proper slope angle is used above the Savart plate in place of a nicol prism; the Wollaston prism is not essential to the proper functioning of the instrument and may be a disadvantage in measurements of light from the brightly illuminated surface of the moon. The separation of the Savart bands is $10'$ of arc and is that recommended by M. Lyot; a separation of $5'$ of arc would probably be preferable in measurements of this nature.

Routine measurements now in progress extend over a complete lunation and include: (1) at the six-inch telescope (a) visual measurements of per-

centage polarization by two different methods; (b) measurements of total intensity of reflected light with the aid of a vacuum thermoelement; (c) measurements of percentage polarization with the aid of a thermoelement and rotatable analyzing prism; (2) at the recently installed 20-inch reflector (a) measurements of relative intensities of reflected light for different spectral ranges from selected areas on the moon's surface; (b) percentage polarization measurements for the same areas with the aid of a thermoelement and analyzing prism; (c) measurements of relative intensity and percentage polarization for different wave-lengths with the aid of the polarization spectrograph at the Cassegrain focus.

Through the courtesy of Dr. C. E. K. Mees of the Eastman Kodak Research Laboratory two 12-inch hollow glass globes have been coated with photographic emulsion. On each globe a negative of the moon is to be projected and photographed. Illuminated from the inside the completed globes will serve to present a more realistic view of the moon than can be rendered by a photograph.

W. S. ADAMS
J. P. BUWALDA
A. L. DAY
P. S. EPSTEIN
F. G. PEASE
EDISON PETTIT
H. N. RUSSELL
F. E. WRIGHT, *Chairman*

PHYSIOGRAPHY

American Geographical Society, New York, N. Y. (For previous reports see Year Books Nos. 29 and 31.)

Godfrey Sykes makes the following report on work carried out under grant of the Carnegie Institution of Washington, supplemented by private funds contributed through the American Geographical Society.

The Colorado River continued during the past year to cross the central part of its delta by means of the channel which it first occupied in 1929, although without any great changes in alignment.

The summer flood stage of 1932 was followed by a falling river during July and August and then, in September, by a most unusual autumnal flood which brought the discharge volume up to 50,000 second-feet for a few days. Thereafter, the river fell to about one-tenth of this figure and remained practically at the same stage throughout the entire winter and early spring.

This prolonged period of steady discharge, somewhat below the winter mean, provided an opportunity of which the contractors took full advantage for pushing forward the work upon the Boulder Dam.

The stream was turned through the first of the four great diversion tunnels in November, and since that time coffer-dams have been placed across the river-bed, the dam-site has been unwatered and work vigorously pushed upon the excavation and foundation for the main structure.

When storage begins and the stilling of the water behind the barrier becomes effective, the character of the river below will entirely change and it will be rapidly transformed from an aggrading to a stabilized or even degrading stream.

By far the greater portion of detrital matter, that has reached and become a part of the existing delta, has come from the San Juan, the Little Colorado and the Virgin, and the supply from these sources, as well as from the upper Colorado itself, will entirely cease with the completion of the dam.

Substantial progress is also being made upon the Los Angeles Aqueduct project, which involves another diversion dam just below and a storage lake and stilling-basin embracing the mouth of the Bill Williams Fork, so that an additional settling process of the residual water passing toward the delta will take place at this point, and for several years at least will eliminate, as a factor in delta development, the distinctive detrital material which is propelled from the mouth of Bill Williams Fork in times of flood.

The upper Gila River and the Salt River are already cut off from contributing further toward the deposits in the delta, by the completion and operation of the San Carlos and Roosevelt Dams, and the discharge in any considerable volume from the lower Gila tributaries is so infrequent that it may be ignored as a serious factor in bringing about hydrographical changes in the delta region.

The unrestricted and unhampered operation of natural forces and processes in further developing and maintaining the delta is therefore about to cease, to be replaced by a controlled river flow of clarified water from

which an additional heavy and regulated toll will have been taken by the Los Angeles aqueduct diversion.

A realization of the far-reaching possibilities of this impending change has largely influenced the course and objective of the field studies carried out during the past twelve months. Attention has been especially paid to observing and recording present conditions in those portions of the delta, the estuary, and the surrounding flood-plains and tidal-flats in which change has been most rapid during recent years. A rapid cursory survey of the entire region which has formed the subject of the investigation was also made during the autumn months of 1932, in order to check up on the topographical and other matter which is being embodied in the full report upon the work. Such slight changes as took place in the dispersal areas as the result of the summer and autumnal floods were reported upon by Mexican cattlemen with whom contacts are maintained.

Activity in channel development has been practically confined to two drainage systems into which the river water now gathers and through which it is delivered into tidewater. Rapid bed cutting is taking place in both at the present time, with the occasional formation of rapids as the gradient of the thalweg is being smoothed out.

The larger and more important of the two, in their present stage of development, has been practically identified as having been the first one formed—at least in part, a portion of the "Boat Slough," which formerly connected the lower Colorado with the Hardy. The details of the capture of this semitidal channel by the newer drainage system are still somewhat obscure, but appear to have involved at least one reversal of current; but as the portion of the channel affected lies within the zone of tidal influence, in which modifications or reversals of direction of drainage are not uncommon, no particular emphasis need be placed upon this circumstance.

The rapid bed-erosion in the two drainage channels shows that both are adjusting themselves to the comparatively steep slope of the recently deposited deltaic cone down which they are developing. A distinct possibility exists at the present time that one or both may eventually form parts of a direct open channel connection between the present virtual ending of the Colorado River and tidewater. Both have now developed definite although extremely tortuous channels, passable with some difficulty in small boats between the grade of the Mexicali and Gulf Railroad and the Hardy, but interrupted by rapids and sluices in places. The more easterly one is, in addition, much involved in tule swamps and thickets. They both have their present heads in a plexus of minor channels and paludal areas which in turn receive their water from the ponded extremity of the Colorado channel.

Under the present accelerated rate of construction at the Boulder Dam, fully three years must elapse before the river can be brought under regulated control, flood danger eliminated along its lower course and in the Imperial Valley, and the further supply of detrital material withheld from the delta and estuary. Much may take place in the way of topographical and hydrographical change in the delta in that length of time, but these parallel drainage channels are at present undergoing such vigorous development, and both have now pushed up so far toward an actual connection

with the main Colorado channel, that there appears to be every probability that they will survive and become permanent features of the lower delta, even though either or both of them fail to become actual links in the formation of a definite open waterway.

Their genesis and early development have been made the subject of special study for two principal reasons; first, because with the impending changes in the delta and the probability that any major topographical features therein will shortly become permanent, facts relative to their formative period will hereafter become matters of interesting geographical record; and, second, because the method of their development—which had been anticipated for several years as the probable way in which an outlet for the Colorado water to tidewater would eventually be reopened—has been entirely typical of the process of backward cutting which has seldom been observed in the flatter gradients of the lower delta, but which reached a spectacular climax in the excavation of the two great chasms of New River and the Alamo through the heart of the Imperial Valley in 1906.

Satisfactory progress has been made with preparation of the results of the investigation for publication.

PHYSIOLOGY

Hartman, Frank A., University of Buffalo, Buffalo, New York. *Studies on cortin and the adrenal cortex*. (For previous report see Year Book No. 31.)

An appropriation by the Carnegie Corporation of New York to the Carnegie Institution of Washington has enabled us to continue our studies on the adrenal gland.

With the assistance of Mr. Charles Winter, it has been shown that adrenalectomized animals (cats, guinea-pigs and monkeys) with or without cortin treatment may pass into a stage of insufficiency from which it seems impossible to bring about recovery. This stage seems to vary with different individuals and may occur with little warning. A stress such as exercise may hasten the onset of this condition. It is possible that a similar irreversible state develops in Addison's disease.

Long-continued insufficiency of the adrenal cortex is dangerous because of the greater difficulty in preventing the onset of irreversibility. Repeated relapses to the point of prostration likewise seem to make recovery more difficult. Patients suffering from Addison's disease sometimes die under treatment with cortin because exacerbation of symptoms is not accepted as a warning that increased dosage should be speedily instituted. This has also occurred in our animal experiments.

It has been shown by J. E. Lockwood and F. A. Hartman that injection of an extract of the adrenal cortex containing cortin delays the onset of symptoms in avitaminosis B₁ and C. These effects are not due to the presence of the corresponding vitamin, for the feeding of the same amount of extract is without effect. Therefore either cortin or some unidentified substance must be responsible. This substance seems to aid in the utilization of the vitamins B₁ and C, because its effect is noted only when vitamin still remains in the organism or during the time that a partial protective dose of the vitamin is being administered.

In the vitamin C series, after single adrenalectomy the activity of the remaining adrenal, as measured by its influence on the onset of scurvy, increased to a degree greater than is found with the two normal adrenals. This increase persisted for three weeks after adrenalectomy.

These observations may throw some light on the hypertrophy of the adrenals in vitamin B₁ and C deficiencies.

The increased size of the adrenals, together with the beneficial effect of cortical extract in vitamins B₁ and C deficiencies, indicates a greater need for cortin or an unidentified substance. Therefore in cortical insufficiency, an abundance of these vitamins seems desirable.

This study has shown that there is some fundamental relationship between certain vitamins and a substance which is probably cortin. It offers concrete evidence in support of a growing conviction in the minds of many investigators that vitamins and hormones are interrelated.

K. A. Brownell, J. E. Lockwood and F. A. Hartman have furnished evidence for the existence of a new hormone in the adrenal cortex. This hormone appears to be necessary for lactation. Adrenalectomized mother rats, although injected with double the quantity of cortin necessary to maintain health, fail to furnish sufficient milk to raise their young. If the new hormone is added they are able to do so. This hormone has been called *cortilactin*. It is separated from cortin by chilling an 80 per cent ethyl alcohol solution to -12° C., when it is precipitated with fatty substances while the cortin remains in solution.

In cooperation with Dr. F. R. Griffith jr., we have studied basal metabolism and urinary constituents in man (three subjects) following injections of cortin, in one set of observations without meat and in another set with calorie and protein intake controlled. Determinations of urea, total nitrogen, chlorides and creatinine were made at frequent intervals for a week or ten days at a time. In the second series, two subjects were on a diet for ten weeks. The results were entirely negative.

Studies on the chemical properties of cortin and improvement in its preparation are being conducted.

We have cooperated with Dr. D. B. Dill of the Fatigue Laboratory at Harvard in a study of the relation of cortin to fatigue in dogs.

Phelps, Earle B., College of Physicians and Surgeons, New York, N. Y.
Study of atmospheric ions in connection with certain public health problems. (For previous report see Year Book No. 31.)

This study continued along the lines described in our last report by means of a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

In exploring the field of possible biological effects of ions the following experiments were tried.

Cultures of a streptococcus were sprayed into an air chamber and allowed to settle on blood-agar plates, the air having first been ionized by means of an electric spark, ultra-violet radiation, or sunlight. The colonies which developed upon incubation of the plates were examined as to number, form and virulence and compared with those obtained by sunlight treatment in normal air. The results varied considerably, a fact which necessitated much repetition, but it could not be satisfactorily demonstrated that changes of significance had occurred. The ionized air did, however, produce a greater reduction in the number of organisms, but here again it could not be determined with certainty whether actual killing had taken place or whether under the influence of the ions the droplets of culture had coalesced.

A number of experiments were tried in which sunned air was drawn over agar plates streaked with organisms. A study was made of the types and number of organisms surviving, as well as some tests on virulence. While many individual experiments yielded encouraging results, the tests on the whole failed to establish the value of the procedure.

Groups of mice were likewise exposed to the sunned air and were subsequently infected with streptococcus. Again the results were negative.

Mice were exposed to an air highly charged with small and large ions of both signs. After a period of treatment the animals were injected with streptococcus cultures. An insufficient number of experiments was performed to establish results with certainty, but the data obtained indicated that under these conditions mice may be made more resistant. The numbers of ions used, however, were greatly in excess of those found under any natural conditions. We hope to continue these experiments.

Mice were housed in a special doubly screened cage which was divided into two compartments. The screens on one of these compartments were connected to a battery furnishing 90 volts in such a way that the air passing into the cage was deprived of its ions, the air in the other chamber being normal. After a month, injections of streptococcus were made. The results were entirely negative. Tests were made also to see whether the germicidal properties of the blood of the mice had been altered toward either the pneumococcus or the streptococcus, but no difference was observed as between the two groups.

Determinations were made daily of the positive and negative ion content and on the positive and negative conductivity of the air at a point about 200 feet above the street-level. The only fact of interest developed was the small number of ions of both signs, values of over 100 per cubic centimeter being exceptional. A moderate correlation is noted with barometric gradient, but this is more likely merely a matter of wind movement as it affects the city smoke.

Although our efforts thus far have been unfruitful in demonstrating any relation between atmospheric ionization and bacterial virulence or animal resistance, we feel that our prospecting in such a new field has covered ground which of necessity had to be explored before further and more elaborate tests could be made.

The work was conducted by Professor E. B. Phelps, Dr. M. L. Isaacs, Miss Joanna Jennings and Mr. Isa Zeiber. In addition, on a part time basis, were Mr. Murry Brimberg and Mr. R. G. Loeffel.

Russell, G. Oscar, Ohio State University, Columbus, Ohio. *Physiological cause of voice quality differences*. (For previous report see Year Books Nos. 28-31.)

One of the most disturbing and baffling difficulties encountered in this investigation had to do with the personal factors involved in X-ray exposures. In the first place, all artists object strenuously to any impediments that are put in the way of ease and freedom during singing. And in the second, it is quite essential that one obtain a photograph of the organs involved just as they operate under unrestrained and as normal conditions as possible. In other words, just to ask the artist to sing a given vowel on a given pitch is hardly a satisfactory procedure, for he immediately becomes self-conscious and probably assumes a position which conforms to some theory he has been taught. This might be something entirely different from what he uses in the course of legato production during the singing of an aria, for example. Then too, a third and still more disturbing factor may be mentioned, *i.e.* the reaction time of the operator who seeks to press the button and make an exposure right in the middle of a given vowel sung at some

specific pitch or place in the aria proper. His reaction time added to that of the subject is so slow as to force the use of a stultifying unnatural prolonged vowel and tone which at best must perforce give vocal organ positions characteristic of only one type of, or manifestation in, singing as it actually is.

These complex problems have been given considerable study and numerous methods have been tried with a view to making the whole process more natural. Our study can now report a degree of success hardly anticipated at the time we began.

It finally became possible to reduce the exposure time to $1/120$ of a second, which made it unnecessary for the artist to sing stultified long notes merely to get a sufficient exposure. Very early in the investigation it also became possible to completely eliminate the swallowing or painting of the vocal organs with any substance such as lipiodol or barium; or the swallowing of a chain, silk thread or other marker to delineate the median line of the tongue; or the usage of any other such artificial means which impede the normal vocal and speech processes. The artist was thereby permitted to take an unrestrained and free position at the side of the X-ray negative without any previous preparation whatever. By means of correction tables any distortion in the resulting X-ray photograph could easily be compensated for.

Parmenter and Treviño published an article in the *Quarterly Journal of Speech* in which they insist that the subject's head be locked in a rigid rack or stanchion, reverting thus to a technique used extensively almost a quarter of a century ago and long since discarded. In this investigation all such hampering devices were ruled out from the beginning, though in some of my earlier vowel investigations a photographer's head-rest had been used, as reported in my book "The Vowel" (Ohio State University Press, 1928). In the present experiments we purposely avoided everything of that nature which would in any way prevent the artist from feeling at ease for normal voice production.

The one thing in our set-up which impeded complete freedom on the part of the subject was the exposure mechanism. After a little over two years' work, we have now perfected an X-ray exposure mechanism including a bank of filters, networks and relays which make it possible to set the timer in advance in such a way that the $1/120$ th of a second exposure will be automatically sprung by the singer's voice; will only occur on a given vowel; will take place any number of cycles after its initiation (which we now usually set at 10 to 15); will occur on a given note; will not repeat itself, thus duplicating the exposure; and at the same time will not interfere with either the synchronized sound record or oscillographic records which we have been making simultaneously with the X-ray exposure. The whole process is, therefore, now completely automatic and eliminates practically all of the objectionable difficulties above mentioned. Once it is set, the singer takes his place beside the X-ray cassette, the accompanist starts in the accustomed regular manner and the complete aria is sung just as the artist is accustomed to do. The exposure makes itself automatically at the proper place. The usual assistants are of course necessary to operate the sound recording apparatus, the oscillograph, and one to see that nothing goes wrong with the X-ray timing and check on the procedure as a whole.

X-RAY PHOTOGRAPHS OF MME. BORI'S VOCAL ORGANS

The X-ray photographs with synchronized sound record accompaniment made of Madame Bori's vocal organs covering a wide range of pitches, voice qualities and vowels were carried through the final complex stages of redevelopment, analysis, classification and study in the course of this past year. The results were reported before the Music Teachers' National Association meeting in Washington, D. C., December 29, 1932. Slides were used in the demonstration. The first analysis was later published in the proceedings of the Society, as: "X-ray Photographs of the Tongue and Vocal Organ Positions of Madame Bori."

That part of the study shows conclusively that at least in the case of this one famous voice, the velar opening into the nasal passages remains closed under practically all circumstances. Except for the relatively small amount of sound energy which could be transmitted through the walls themselves, it may therefore be said that nasal resonance is not made use of. This observation but adds to those previously made, which indicate that this theory so commonly invoked to account for voice quality differences will in all probability have to be decidedly modified. Bori's X-rays also show that the larynx does not necessarily always rise on all pitches and fall on low pitches. Furthermore, it would appear that it does not retain a constant position anchored to the spinal column by means of the powerful constrictor muscles, but shifts its position quite constantly. A more careful study will be necessary to ascertain just what the purpose of any such shifts may be, if such purpose there be. They likewise confirm the previous observation to the effect that the pharynx is usually distended on the vowel *i* regardless of pitch; and that the epiglottis or areas in the neighborhood of the tip thereof regularly constricted, or, in other words, that the back of the tongue regularly "gets into the throat" in order to produce a clear vowel *a* (ah). Theories that have been based upon the assumption that tight constricted or throaty tones were traceable to the position of the tongue will therefore probably have to be modified. We have previously reported on vocal lip-motion picture experiments showing that constriction in the superior larynx is really responsible. Madame Bori was prevailed upon to produce one bad strident, tight tone, and it was of interest to note that the X-ray showed the pharyngeal cavity to be more distended than usual. But the interior larynx is obviously very constricted.

During the past year demonstrations were also made before the Academy of Medicine of Cincinnati, the Minnesota State Teachers' Association, and several demonstrations were made abroad, particularly in Vienna before the International Kongress für Logopädie und Phoniatrie, in Amsterdam before the Congrès International Des Sciences Phonétiques as well as one at the International Psychological Congress in Copenhagen before a group arranged for Professor Pavlov, the Russian scientist. A paper was also given before the International Congress of Teachers of the Deaf in Trenton, New Jersey, June 1933.

Jack C. Cotton, of our group of assistants, who is conducting an investigation attempting to ascertain the resonance characteristics of soft-walled cavities, likewise presented the first preliminary results of his investigation

before the Acoustical Society of America, November 29, 1932, which met in Ann Arbor, Michigan.

This year no expenditures were made from the appropriation by the Carnegie Corporation of New York to the Carnegie Institution of Washington for our work, since it has been deemed wise to conserve these funds just as much as we can until as many as possible of the X-ray experiments can be carried through redevelopment processes and be analyzed and studied so that funds will be available for carrying this work on as far as feasible.

PSYCHOLOGY

Ruger, Henry A., Teachers College, Columbia University, New York, N. Y.
Studies on the theory of surfaces. (For previous reports see Year Books No. 27, 29-31.)

These studies have been continued with funds made available by the Carnegie Corporation of New York and the Carnegie Institution of Washington.

Sir Francis Galton in 1884, in his First Anthropometric Laboratory at South Kensington, measured seventeen characters, each on a population of something over 7000 males whose ages ranged from 6 to 82 years. Approximately 1800 females of wide age range were measured for the same traits. This data seems as yet unrivaled as to number of such traits measured and size of sample for the age-range involved. It is only recently, however, the statistical reduction of this material has been comprehensively undertaken.¹ In the *Annals of Eugenics* (vol. II, parts I and II, 76-110, April 1927) appeared an article on the Growth Curves of Certain Characters in Man (males) by Henry A. Ruger with the assistance of Brenda Stoessiger. Included in this paper were the frequency spreads for each of the fifteen traits employed, correlated with age. There were also trend curves for means and for absolute and relative variability plotted against age.

The inter-correlations of eight of these traits corrected for age are presented in a recent study by Professor Karl Pearson, of University College, London, and Henry A. Ruger, entitled "On the Interrelationship of Certain Characters in Man (males)" (*Annals of Eugenics*, vol. V, parts I and II, pp. 59-104, Jan. 1933). This study was made possible by aid from the Carnegie Corporation of New York as administered by the Carnegie Institution of Washington, D. C.

A closely related investigation is that of age-curves and age corrected correlations on Galton's data for 1800 women by Dr. Ethel M. Elderton and Margaret Moul, published in volume III of the *Annals of Eugenics*.

Further studies under the auspices of the Carnegie Institution have been planned and partly executed. Tables, diagrams and plates have been made showing the presence or absence of age trends in correlations of traits previously corrected for age differences. Approximately 2400 measures of correlation in partial populations are given, along with the corresponding values in the total population, all scores having been age-corrected. Similar tables have been constructed for the product moments of lowest order. Considerable work has been done on certain characteristics of the correlation surfaces for the total population.

Sir Francis Galton secured, in addition to age, occupation, birthplace and place of residence, measurements of seventeen traits as follows: stature, sitting-height, span, weight, pull, grip of stronger hand, grip of right hand, grip of left hand, swiftness of blow, vital capacity, visual acuity, highest

¹ For an account of the methods of measurement see the *Journal of the Anthropological Institute*, vol. 14, 205-221, 275-287.

audible pitch, sense of perpendicularity, error of bisection, error of trisection, goodness of color sense and eye color. The first fifteen, beginning with stature, were reduced for age in the *Annals of Eugenics* (vol. II). Four "static" traits, stature, sitting height, span and weight, and four dynamic traits, pull, stronger grip, swiftness of blow and vital capacity, were examined for age corrected correlations in the article in *Annals of Eugenics* (vol. V). A brief statement of some of the results of this last mentioned study follows.

In general, absolute variability of the age corrected scores was greater for men than for women. This did not hold, however, for relative variability. Span is markedly greater than stature in men, but is less than stature in women. The variability about the array means is remarkably uniform; being in general homoskedastic, or slightly U-shaped or J-shaped with but little curvature in the center of the tables. First, second or third degree parabolas seemed to suffice as trend lines, *i.e.* regressions. In most cases the relationship was apparently linear. Blakeman's test failed to show non-linearity when it seemed evident from the trend of the plotted array-means. A detailed comparison of graphic results with Fisher's test for linearity is given. The twenty-eight correlation coefficients or intercorrelation of the eight traits range from 0.153, swiftness of blow and sitting height to 0.818 for stature and span. The correlation of span and stature is higher than that between sitting height and stature. The intercorrelations of the static characters is higher than the intercorrelations of the dynamic group and higher than the correlations between the static and dynamic groups. With the exception of grip, dynamic and static characters have smaller intercorrelations in women than in men. In particular, vital capacity is much less correlated with stature, sitting height and weight in the case of women than with men. When weight enters, the other trait of the pair tends to non-linearity. The interrelation of dynamic traits is in general non-linear. Swiftness of blow shows the lowest correlations. The article includes twenty-eight correlation spreads of age-corrected scores for 7000 males and twenty-eight diagrams showing linear or curvilinear regression lines with skedastic belts about the array means and standard-deviation yardsticks. The regression equations are reproduced. Additional tables present comparative results as to means, variabilities, correlations and linearities.

As noted above, work is going on in connection with sampling and correlational surfaces.

Acknowledgment is gladly made of very competent assistance by Mr. David Bachner, Miss Florence Ropp, Kurt and Antonia von Brand, Gertrude Johns and Georgie J. Ruger.

SEISMOLOGY

REPORT OF THE ADVISORY COMMITTEE

(FOR PREVIOUS REPORTS SEE YEAR BOOKS NOS. 20-31.)

GEODETIC WORK IN REGIONS OF SEISMIC ACTIVITY ¹

As in other recent years the Coast and Geodetic Survey was again authorized by law to spend \$10,000 of its regular appropriation for geodetic surveys in regions of seismic activity. The areas in which the work was done were selected after conferences between officials of the bureau and members of the Advisory Committee in Seismology of the Carnegie Institution of Washington.

During the past year the following work was accomplished:

An arc of close triangulation from San Fernando to Bakersfield, California, involving 12 first-order and 75 second-order stations. The arc is 110 miles in length and crosses five major zones of active faulting.

A preliminary survey was also undertaken in the vicinity of Taft, involving an area of some 65 square miles for the purpose of determining the amount and rate of horizontal surface movement at a point where an oil company had reported that horizontal displacements had actually sheared off several drilled wells. Twenty-five triangulation stations have now been placed in this area, the locations of which were selected by the chief of the triangulation party in consultation with Dr. Buwalda of the Advisory Committee in Seismology and officials of the oil company. Visible surface displacements in this region have been reported locally from time to time over a period of several years. The stations now established will provide a basis for a more precise determination of the direction and rate of this movement and perhaps furnish some idea of its extent.

Of especial importance to the seismologist also is an arc of triangulation extending along the California coast and throughout the length of San Francisco Bay. The work in the Bay is of first-order accuracy, while that along the coast is of second-order. All of the stations of this coast triangulation can be used in determining horizontal earth movements should an earthquake occur in this area adjacent to the San Andreas fault.

Before the end of the year covered by this report plans had also been made to repeat the observations at triangulation stations and along the lines of levels lying near Long Beach, California, the scene of the destructive earthquake of March 10, 1933. It was expected that this work would be done during the summer of 1933. The opportunity thus afforded to measure accurately the major displacement due to a moderately strong earthquake is the first since these cooperative studies of California earth movements began some eight years ago. The results will be studied with the greatest interest.

At the request of the Chairman of the Advisory Committee in Seismology, the Director of the Coast and Geodetic Survey has agreed to provide a line

¹ From information furnished by Major William Bowie, Chief of the Division of Geodesy, U. S. Coast and Geodetic Survey.

of levels across the fault along which an earthquake occurred in Nevada in December 1932. A line had already been planned across the state and, by a short shift in position, it was made to cross the fault zone in the most important place that was accessible. The work will be done during the fiscal year 1934.

It will be a matter of very general interest among students of earth movements that the past year has been a most active one in the field of geodesy in the United States because of a large allotment received by the Coast and Geodetic Survey from funds appropriated by Congress for emergency work. A large part of this supplementary allotment was devoted to geodetic surveys.

As a result of these increased appropriations, large additions were made during the year to the national triangulation and leveling nets of the United States. During the 12 months ending June 30, 1933, 3625 miles of arcs of first-order triangulation, 11,590 miles of first-order leveling, and 2835 miles of second-order leveling were added. The total amount of triangulation in the net on June 30, 1933, was approximately 38,500 miles of arcs. The leveling net, comprising both first- and second-order work, included 83,800 miles at the end of the year.

The Coast and Geodetic Survey is now working on a plan which calls for the spacing of arcs of triangulation and lines of levels of first-order at intervals of about 100 miles over the entire country. The intermediate areas will be controlled by second-order triangulation and leveling of such extent that no place in the country will be more than about $12\frac{1}{2}$ miles from a triangulation station or a leveling bench mark when the nets have been completed. If the rate of progress made during the present year could be continued, the control surveys could be finished in 5 or 6 years. In addition to these surveys, detailed horizontal and vertical control surveys to serve as the bases for topographic mapping and engineering projects will also be done.

All of the triangulation and leveling in the fundamental nets are of value in seismological investigations. Eventually, when the whole country is covered with networks of triangulation and leveling, with the 25-mile spacing of arcs and lines, it will be possible to measure vertical and horizontal movements of the earth's surface close to any region where an earthquake may occur. Even the detailed triangulation, traverse and leveling done for the control of topographical maps can be used in determining the displacement that occurs during an earthquake.

As rapidly as practicable, the arcs of triangulation and lines of levels are adjusted into the national nets. As stated in earlier reports, a very complete adjustment of the triangulation and leveling nets of the country has been made during the past few years. The Coast and Geodetic Survey is therefore now in a position to furnish, for thousands of triangulation and leveling stations, what may be considered final geographic positions and elevations. Future changes will ordinarily be made only as a result of earth movements.

At the time this statement is written, the Coast and Geodetic Survey is expanding its geodetic surveys even faster than during the past 12 months. This has been made possible by an allotment of funds to the bureau from the appropriation for the National Industrial Recovery Act. Of these funds \$1,050,000 will be used for geodetic surveys. In addition, there will be avail-

able for geodetic surveys during the fiscal year ending June 30, 1934, approximately \$125,000 of the regular appropriation to the bureau.

It also happens that during the past few years the funds available for printing have been very meager and, in consequence, very few of the more recent geodetic results have appeared in print. This condition will be remedied soon, as a substantial part of the new funds allotted to the bureau may be used in publishing available data. It is hoped that reports of geodetic surveys in a number of states may appear in print in the next 12 months.

During the year the variation-of-latitude stations at Ukiah, California, and Gaithersburg, Maryland, were maintained in continuous operation. Observations were also made during the year at stations Carloforte, Italy, Mizusawa, Japan, and Kitab, Turkestan. Preliminary reports prepared by Dr. H. Kimura, Director of the Central Bureau of the International Latitude Service, have appeared from time to time giving the results of these observations. The final results from 1912 to the present time will soon be printed as volumes VI and VII of *Resultate des Internationalen Breitendienstes*.

EARTHQUAKE STUDIES OF THE SEISMOLOGICAL LABORATORY ¹

During the year under report the work of this program, which has been described previously both in general and in detail, has gone forward satisfactorily and steadily, notwithstanding that it has been affected greatly by the occurrence of local earthquakes in extraordinary number (including a multitude of aftershocks of the major earthquakes in Nevada on December 20, 1932, and of the local strong shock near Long Beach on March 10, 1933), so that the measurement of seismograms and the circulation of regular reports based on these measurements are now in arrears.

Since presentation of the last previous report, comparatively little new work has been undertaken because of the considerable amount of uncompleted work under way at the time and the increasing requirements of the routine study of the recorded shocks which have culminated in a number far too great for prompt disposal with available facilities.

The volume of interpretation and measurement of all (or a very great part) of the earthquakes usefully recorded has also been augmented by the completion and installation of vertical-component seismometers which are now in operation at all seven stations of the local network. As a result, not only are there additional seismograms to be inspected and measured, but since these instruments are more sensitive than the short-period torsion seismometers in use at the auxiliary stations more earthquakes are recorded usefully, with a consequent increase in the number to be studied and measured.

For the present, reasonably prompt reports can be issued only on the larger local earthquakes. An effort is being made to determine a suitable modification of the previously adopted routine procedure which will make reasonably prompt and regular reports possible. In selecting the shocks which merit attention in the first instance, the *magnitude scale* developed last year is proving very useful. It is hoped that an adequate discussion of this scale can be published in the near future.

¹ Extracted from the Annual Report of H. O. Wood, Research Associate in Seismology.

At the time of the shock of December 20, 1932, which event disrupted routine measurement of the records, measurement of the seismograms for September 1932 had been completed, but the usual report on the local shocks had not been prepared. The shock of March 10 followed before regular procedure could be restored, with the result that the local earthquake report for August 1932 is the latest yet issued. Measurement has gone forward, however, as steadily as possible; but the arrears at the date of writing are very considerable.

During the interval May 1, 1932, to December 20, 1932, about 850 local earthquakes were registered sufficiently well to permit measurement. Since the date of the Nevada shock, such shocks number thousands, as yet not counted even approximately.

During the interval May 1, 1932, to February 28, 1933, some 346 teleseismic shocks were registered, measured and reported. Few of these call for special mention. Two large shocks of deep-focus type, originating in Manchuria, were recorded on September 3 and on November 13, 1932. A great shock of normal character, destructive in China, was well recorded on December 25, 1932. A shock on January 4, 1933, originated near the position 28° N. Lat., 126° W. Long., off the edge of the continental shelf. On January 21, 1933, large amplitudes were recorded from a great shock which originated near the antipodes of Pasadena, at about 40° S. Lat., 59° E. Long. On March 3, 1933, a great earthquake off the coast of Japan was registered, and on June 24, 1933, one which was destructive in Sumatra.

During the first nine months of 1932 the seismic activity in and adjacent to Southern California exhibited a pattern similar to what is now considered to be usual here. Small shocks in the coastal area of San Luis Obispo and Santa Barbara Counties were registered frequently, also near Santa Barbara, near Tejon Pass, in the region of Owens Valley and thence to the eastward, in various parts of the Los Angeles basin and the adjoining submarine area of the San Pedro Channel, and in the district which extends northward from the San Bernardino Mountains out into the Mojave desert. (Shocks in the Mojave desert area were conspicuous in the early part of 1932.) While, as has been usual, small to moderate shocks were frequent roundabout the head of the Gulf of California during these nine months, shocks were relatively infrequent in the more northerly region about Imperial Valley and along the San Jacinto fault.

About October 1 a minor change in this activity pattern appeared. Fewer shocks occurred in the Mojave desert area, while shocks in the Los Angeles basin and to the east became more frequent, with some of greater magnitude. From October 7 to 10 a swarm of earthquakes occurred which originated not far west of Calexico. Some of these were felt sharply in the southern part of Imperial Valley. The largest shock of this swarm occurred on October 9, after which the activity diminished, although shocks in this general region were registered thereafter about as frequently as in previous years. This is the most striking of a number of occasions when groups of shocks have occurred in the Imperial Valley region in which the first shock was definitely not the strongest. Similar occurrences have taken place elsewhere in California in recent years, as well as in earlier years, but such cases are comparatively few.

At 10.10+ p.m., Pacific Standard Time, on December 20, 1932, a major earthquake occurred in west-central Nevada some 500 kilometers north (and a little east) from Pasadena and some 175 kilometers north-northeastward from Tinemaha station. This shock was felt over a very large area in the western United States. It was registered at seismological stations all over the world—reports having been received from the most remote stations situated at Tananarive (Madagascar) and at Cape Town. This earthquake was registered excellently at all our stations. Innumerable aftershocks were registered also, especially at Tinemaha where the sensitive vertical-component instrument registered a practically continuous succession for many hours. If it proves possible to fix the various places of origin with sufficient accuracy, this will become an extremely valuable body of data. However, complexity of shock origin may prove a source of confusion. Cracks, fissures and minor fault-displacements at the surface in firm rock were found throughout an area perhaps 80 kilometers long, north and south, by 10 to 20 kilometers wide, east and west, in the region of origin. Moreover, there is strong suggestion that the aftershocks emanated from three or four distinct sources, possibly more. Besides this, a fairly large area in west-central Nevada and east-central California appears to have been disturbed by other scattered shocks, following that of December 20, which have ranged from minor tremors up to earthquakes of potentially destructive magnitude. Only the desert character of the country affected, with a practical absence of population and works of construction, especially in the immediate vicinity of the origin of the major shock, averted a disaster, or a series of them, of considerable magnitude.

The occurrence of the major shock in Nevada had no recognizably significant effect on the activity in the Southern California province. As it happened, however, shocks became fewer in the Los Angeles basin area after this event, but more occurred in the region of the San Bernardino Mountains and the Mojave desert.

At 5.45+ p.m., Pacific Standard Time, on March 10, 1933, the strong local shock which doubtless will be known as the "Long Beach Earthquake" took place. Information regarding this has already been made available in a mimeographed report circulated under date of April 4, 1933, and in a printed article dated May 10, 1933, published by the writer in the April 1933 number of the Bulletin of the Seismological Society of America.

It may, however, be of interest to place on record here a preliminary bulletin given out to the press shortly before midnight on March 10, 1933—based on the records of the "visible" ink-writing seismograph:

"At 5:54:20 p.m. today our instruments began recording a moderately strong local shock, which was sharply felt in the Laboratory, and which was evidently sufficient to cause damage near its source. The source appears to be sixty or seventy miles southeast of this Laboratory, but because of peculiarities in the geological structure a precise distance can not yet be given. A large number of aftershocks have been recorded with very brief interruptions. Three or four of these have been stronger than the rest and have been barely felt at the Laboratory. One or two hundred shocks have been recorded on the less sensitive instruments, and it is prob-

able that the more sensitive instruments will record a great many more. It is to be expected that shocks of varying intensity will continue for many hours, and perhaps for days or weeks. It is usually the case, however, that the first shock is the strongest. It seems probable that the origin is in the San Pedro Channel, within the triangle formed by Point Firmin, Avalon and Laguna Beach. Precise location will not be possible before the receipt of records from our auxiliary stations next week."

The distance given in the bulletin proved to be overestimated, due in part to the quality of the ink-written records but chiefly to the geological peculiarities mentioned. The deepest part of the Los Angeles basin lies directly on the path from the region of origin of these shocks to Pasadena, and this is believed to affect the propagation of seismic waves in such a way that certain phases were not correctly identified on the ink-written seismograms.

Following the Long Beach earthquake, what appeared to be a marked change in the nature and pattern of activity in the Southern California province took place. Shocks since its occurrence seem chiefly to have been aftershocks of this event. However, a few earthquakes have been registered from other sources, with a slow increase in the number of such shocks toward the end of the period under report, which probably indicates a gradual return to more normal general activity.

Though its source lies well outside our own immediate province, mention should be made of a shock on May 16, 1933, which appears to have centered on the Haywards fault in Central California. This shock barely reached destructive intensity. Its association with activity in Nevada and in Southern California is problematical.

Though not a seismic event, a terrific explosion early in the afternoon on June 2, 1933, at a gasoline absorption plant on Signal Hill, a little north of Long Beach, is a matter of considerable interest. Though the explosion took place at a small height above the ground surface, possibly two to three hundred feet or a little more, it apparently struck a sharp and powerful blow on the earth surface with a resultant earth wave-system which was registered at Pasadena, Mount Wilson and Riverside. Later an effect due to the arrival through the air of the explosion-wave was registered at Pasadena and Mount Wilson. Presumably the sharp air wave, which was both heard and *felt* plainly at Pasadena, struck the steep hillsides near these stations with sufficient force to generate *locally* ground vibrations strong enough to affect the seismometers, since these are shielded adequately from effects transmitted directly through the air. It is of interest that the records of this explosion show a close resemblance, except apparently that greater distance of source is indicated, to a number of puzzling records previously written at Pasadena and Mount Wilson.

In the study of certain teleseisms, for which a large number of records have been brought together here from many widely separated stations, it has been noticed that there exists one unrecognized source of error in the usual methods of calculating distance. Such calculations are usually based on the assumption of a spherical earth. The ellipticity introduces directly only a small error; but when *geographic* latitudes are used, as is customary, there is a much larger error. In the extreme case the angular distance calculated in this way may differ from that calculated by using the more appro-

priate *geocentric* latitudes by as much as 23 minutes of arc of a great circle. A general use of geocentric latitudes is recommended, whereby such errors are easily eliminated. A joint paper by Dr. Gutenberg and Dr. Richter, in which this matter will be discussed, is in preparation.

INSTRUMENTAL EQUIPMENT

For more than a year past we have had under development a "portable seismometer station," an assembly of apparatus in transportable form suitable for the registration, at different selected points, of earthquakes, blasts and similar disturbances. A recording drum like those regularly in use at our seismometer stations, but in this case rotated by a weight-driven power-clock of the familiar kind, is mounted with a short-period galvanometer and a suitable optical system in a substantial housing on an automobile trailer. This also carries a radio-code receiving apparatus the record from which is written alongside (or in between) the lines of the seismogram. The trailer also carries a spring-driven time-marking clock, the necessary batteries, and other required equipment; and the housing is so designed that the photographic record sheets may be changed safely and with reasonable convenience when the equipment is outdoors in bright sunlight. In use, a vertical-component seismometer of the Benioff type (but of smaller size than the standard instrument) is placed on the best ground, or rock, available at a nearby point, and protected from wind, etc., by a cylindrical metal housing with a top cover. Wires from this are led to the galvanometer. The records thus obtained are directly comparable with those written at our regular stations, though the instrumental sensitiveness and magnification are different. The sensitiveness of the portable instrument is subject to controlled variation so that it may be adapted to conform with the local conditions encountered. The development of this equipment, as a whole, is not yet completed, but it had reached a usable status shortly before the Long Beach shock on March 10, 1933.

Immediately after the Long Beach shock temporary adjustments and connections were made and the portable station was taken into the field and used to obtain successful records, for a few hours run at each of three temporary stations in the more heavily shaken region, within the first week after the main shock. One of these temporary stations, near La Bolsa northwest of Huntington Beach, proved to be within 10 kilometers of the principal epicenter. Then needed improvements were made in the instrument assembly, after which it was taken to Santa Catalina Island and run for two days in order to obtain data with respect to peculiarities in wave-propagation, in this direction from the source of the shocks, expectable on the basis of known peculiarities in the geologic structure.

The usefulness of the record obtained depends markedly on the nature of the ground. On the less stable ground, as at La Bolsa and Santa Monica, the sensitivity has to be reduced to a point where only the larger shocks are recorded, so that if a large shock has a small beginning it is not recorded. Where rock is available at the surface, as at most of the other locations, no difficulty has been experienced with the registration.

Further developments have been made with the "wave seismograph" previously described. The name for this instrument has been changed to

"linear-strain seismograph." The former designation was chosen because of a rather loose analogy which this instrument bears to the wave antenna of radio. Actually, however, the response of this instrument is produced by linear strains of the ground. Therefore it has seemed better to adopt a name which is more truly descriptive.

A galvanometer with a period of 35 seconds has been operating in connection with the strain seismometer for a number of months. The behavior of this combination appears to have substantiated fully the theoretical characteristics which were predicted for it. Thus it appears to provide an ultra-long-period seismograph which is completely free of drift due to earth-tilt or other disturbances introduced by such tilt. It has been found necessary to insulate the rod, or pipe, with a layer of asbestos-compound to prevent responses by the long-period galvanometer to fluctuations of temperature in the tunnel in which the rod member of the assembly is installed. Thus insulated, the stability of the instrument is found to be high.

In the seismogram of the large Japanese earthquake of March 2, 1933, which was recorded with the assembly as described, S and L waves having periods of 60 and 90 seconds, respectively, were recorded with the maximum amplitudes shown on this record. Surface waves having periods of three and one-half minutes were the most prominent features of the later part of this record.

After an extended theoretical study the design of the transducer, the current-generating device used with the several different electromagnetic seismometers, has been changed radically. In the newer form the efficiency has been raised to such an extent that the reaction of the output currents is sufficient to damp the pendulum-action of the inertia-reactors without the aid of the oil-damping mechanism previously in use. Consequently the energy expended in churning the oil in the older design is now available as an increase in output current to actuate the galvanometers. An additional gain from the higher efficiency of the new transducer is an increase from 0.5 mm. to 2.0 mm. in the length of the air-gap between the armature and the pole-pieces of the magnet. This increases in the same proportion the effective stability of the seismometer. This new transducer has been adapted to both the vertical and the horizontal-component instruments.

In addition to the new transducer other changes have been made in the design of the vertical-component seismometer. The supporting spring has been mounted in a cylindrical recess along the axis of the inertia-reactor, eliminating the supporting superstructure, with a consequent reduction in the overall height of the instrument to about one-half its former value. Heavy steel ribbons have been substituted in place of the bicycle spokes used as guides and supports in the three-way suspension of the earlier model.

With the aid of Mr. A. B. Nomann of the Department of Geology of the California Institute of Technology, Mr. Benioff devoted a good deal of time and energy for some months to the redesign and further development of special electromagnetic seismographs, together with auxiliary amplifying and recording apparatus, and attendant aids for effective field use, to serve in the study of shallow geologic crustal structures by the methods employed in geophysical prospecting. The expenses of this experimentation, apart from Mr. Benioff's share in it, were borne from special funds made available

to the Department of Geology of the California Institute. As an outcome, excellent equipment was developed, which has been used with much success in the field work of the Department of Geology of the Institute. The seismometric instruments developed for this are both highly sensitive and very reliable and also very rugged. On one occasion one of them fell from the field truck while it was running at good speed and rolled for a considerable distance. No damage resulted to the instrument and it did not even require readjustment.

The Long Beach Earthquake afforded opportunity for investigation of the effect of aftershocks in high buildings, at different heights from foundation, or basement, upward. Though work of this kind lies outside the plan of this program of research, we were able and glad to be of assistance to Professor R. R. Martel of the Department of Civil Engineering of the California Institute of Technology in prosecuting some studies along these lines. Existing apparatus no longer in use was redesigned and reconstructed for the purpose and made available to Professor Martel. The cost of this reconstruction was borne by California Institute from a special fund placed at the disposal of Professor Martel.

Four torsion seismometers were remodeled according to a design by Mr. Benioff, which is novel in certain respects. The steady-mass, or inertia-reactor, consists of a rectangle of heavy copper wire suspended by a heavy bronze ribbon under a tension of about 10 pounds weight. The period of the system is approximately 0.75 seconds, and adequate damping is provided by a permanent magnet with pole-pieces specially shaped to increase the efficiency of the damping. Optical magnification was adjusted to the value, 30x. All parts, the seismometer, optical system and recording drum, are tied together in a rigid mounting by means of structural channel steel, so that the whole assembly forms a single unit which may be moved about without disturbing the adjustments.

These instruments were operated in pairs at several different locations for a number of weeks, with one instrument installed near the building foundation, as in the basement or on the ground floor, and the other near the top, or on an upper floor. Time marks were recorded simultaneously on the two recording drums by means of a single contact-making clock.

Work with these instruments in the buildings was conducted by Professor Martel. Thorough study of the records has not been completed, but it appears that the movements at the top of some buildings are as much as three times as great as the corresponding ground movements. Resonance effects appeared to be very pronounced in all the buildings tested.

It is a pleasure to record that the strong-motion, displacement-measuring, torsion seismograph designed by Dr. Sinclair Smith and installed at Pasadena has operated effectively on several occasions, in particular, during the Nevada earthquake of December 20, 1932, and the Long Beach earthquake of March 10, 1933, and numerous of its aftershocks. Thorough analysis of these records will yield results certainly of great interest and doubtless of much importance also. Other development items, temporarily in abeyance because of the illness of Dr. Smith, are the ultra-long-period horizontal pendulum (for the registration of tilt and of long-period seismic

waves), the large-scale, horizontal-pendulum, displacement instrument for registering strong motion, the variable-frequency, multiple-pendulum, torsion assembly for the selective registration of predominating seismic frequencies on the principle of resonance, and the simple pendulum air-damped seismograph.

I regret to have to record that, owing to faulty installation, for which no one person can be held at fault, the Anderson multiple, leaning-pendulum intensity-meter failed to operate during the Long Beach shock, the only shock strong enough to have afforded an adequate test of it since its completion.

An interesting development in which we have had only a small part has been carried out by Mr. Halley Wolfe, a graduate student in Electrical Engineering at the California Institute of Technology. Utilizing an independent source to provide an additional independent beam of light which falls upon an orifice in front of a photoelectric tube, or cell, so as to cause variation in the area illuminated when the mirror is oscillated by variations in current from the seismometer, he has devised a very successful, visible-writing mechanism which records with much fidelity the longer-period excursions of the galvanometer mirror, writing with ink on bond paper on a regular recording drum. In its present status the assembly can not, of course, compete with the direct photographic recording in fineness of the recording line or in fidelity of response to all movements of the galvanometer mirror, fast as well as slow, but it yields a serviceable record nevertheless.

At a meeting of the Seismological Society of America held on April 8, 1933, at the University of California at Los Angeles, informal presentations of the following papers were made by members of the Seismological Laboratory staff.

Recent Developments in Electromagnetic Seismographs, by Hugo Benioff.

Advantages of Using Geocentric Latitude in Calculating Distances, by B. Gutenberg and C. F. Richter.

Preliminary Results on Three Recent Great Earthquakes, by B. Gutenberg and C. F. Richter.

An Instrumental Scale for Earthquake Magnitude, by C. F. Richter.

Papers were submitted for presentation at the Fifth Pacific Science Congress at Vancouver, in June 1933, as follows:

Seismological Research in Southern California, by Harry O. Wood.

A New Electromagnetic Seismograph, by Hugo Benioff.

Only two papers have actually been published during the year under report, largely in consequence of the restricted financial condition of the Seismological Society of America, in whose Bulletin most of the papers appropriately appear. These papers were:

Experiments Testing Seismographic Methods for Determining Crustal Structure, by B. Gutenberg, Harry O. Wood and John P. Buwalda, *Bul. Seismological Soc. Amer.*, vol. 22, No. 3, September 1932;

Preliminary Report on the Long Beach Earthquake, by Harry O. Wood, *Bul. Seismological Soc. Amer.*, vol. 23, No. 2, April 1933.

In view of financial limitations resulting from the continued depression, no specific recommendation for new development is offered this year. It is hoped, however, that the current program can be maintained.

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ARTHUR L. DAY, *Chairman*
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HARRY FIELDING REID
BAILEY WILLIS
Advisory Committee in Seismology

Willis, Bailey, Stanford University, California. *Studies in comparative seismology*. (For previous report see Year Books Nos. 29, 31.)

A full account of the work in Comparative Seismology was given in Year Book No. 31, pages 372-377. During the past year Dr. Willis has continued the preparation of the monograph on *African Plateaus and Rift Valleys*. The facts relating to the development of the plateaus and those pertaining to the Western zone of the rift valleys have been assembled and written up. The great Eastern rift valley remains to be studied in detail in the same manner. The results thus far yield a satisfactory explanation of the peculiar structural features of East Africa, in keeping with the evidence regarding similar structures in California and other regions examined in the course of this work. It is anticipated that the monograph will be published during 1934.

A paper on Isthmian Links, dealing with the problem of inter-continental connections and climatic conditions in the Permo-Carboniferous has been published in the Bulletin of the Geological Society of America. It is a by-product of the dynamic studies in seismology, presenting an argument for suboceanic orogeny.

The practical aspects of earthquake studies have been advanced by the occurrence of the Long Beach shock and by a sharp tremor on May 16, 1933, east of San Francisco. In the latter city a committee has been formed by the Junior Chamber of Commerce to promote public interest in strengthening existing buildings to resist lateral forces, with a view to making San Francisco safe against earthquakes. Dr. Willis is a member of the committee and continues his work in that interest.

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